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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*The Morphogenesis of Platystrophia. A Study of the Evolution of a Paleozoic Brachiopod;* by EDGAR ROSCOE CUMINGS.

FEW fossils present features of as great interest and importance, both to geologists and zoologists, as the Brachiopoda, and among them, few are as familiar as the genus *Platystrophia*, the "Orthis lynx" of collectors. Wherever Ordovician rocks are exposed the geologist may expect to meet with this ubiquitous and characteristic genus. The regularity with which it turns up in collections from new localities is little short of amazing, and perhaps, if familiarity breeds contempt, accounts for the indefinite and hazy notions current as to its real history and the interrelations of its component elements.

The writer has made an attempt in a preliminary paper to obtain some measure of the variability of *Platystrophia* and out of that study has grown a deeper interest in this form and a deeper insight into its history. The present study is based upon the method of investigation of post-embryonic growth stages, which we owe to Alpheus Hyatt and his able exponents of the present day, Beecher, Jackson, Smith and others. I have endeavored to make full use of specimens representing all stages of growth and all the elements of the range and distribution of *Platystrophia*. The *mere study of growth stages* has not been deemed adequate unless supplemented by series of adults; and it is hoped that in this way is escaped the error of depending on one class of evidence. That this method thus supplemented has proved potent in discovering unsuspected relationships among the members of a genus which has attracted widespread attention for nearly a century, will be evident to those who follow the present discussion to its close.

The order of presentation is, first, the development of *Platystrophia* under the heads *Nepionic*, *Neanic*, *Ephebic* and

*Gerontic** stages: second, a critical discussion of the several adult types variously known as species and varieties of *Platystrophia:* and third, a general résumé and discussion of the history of the genus and the laws of its evolution.

The material used in this investigation belongs in part to the author's collection, which contains several thousand specimens coming from every division of the Cincinnati Group of the Ohio Valley. In addition the Yale Museum contains, besides many specimens from Cincinnati and vicinity, specimens from the Trenton of New York, Kentucky, Tennessee, and Minnesota; from the Galena of Minnesota; from the Clinton of New York and Kentucky; from the Silurian (Niagara) of Anticosti and the Island of Gotland; and from the Ordovician of Wesenberg, Russia. Mr. P. E. Raymond very kindly gave me a series of specimens from the lower Trenton of Crown Point, New York; and Mr. C. J. Sarle of Rochester, N. Y., loaned me a series from the Clinton of that vicinity. Dr. J. M. Clarke loaned for study specimens from the Rysedorph conglomerate (basal Trenton) in the vicinity of Albany, N. Y. Mr. Chas. Schuchert of the U. S. National Museum loaned specimens from his private collection and the collection of the museum, representing the following localities and horizons: St. Petersburg, Russia (Ordovician); Gotland, Sweden (Silurian); Gasport and Lockport, N. Y., Eaton and Dayton, Ohio, and Osgood, Indiana (all Silurian). Prof. R. T. Jackson of Harvard University with great kindness allowed me to study their unrivalled collection of *Platystrophia*, containing many thousand specimens from Cincinnati, Ohio (Ordovician). Dr. G. F. Matthew sent me for study his types of *Orthis lenticularis* from St. John, N. B. To Prof. H. S. Williams of Yale University the writer is indebted for opportunity to examine material from the Ordovician of Arkansas, and for suggestions which his wide acquaintance with kindred subjects renders of especial value. To Prof. C. E. Beecher, who has afforded me every facility and encouragement during the prosecution of this work, the author is under deep and lasting obligations.

Development of Platystrophia.†

I. *Nepionic stages.*—The youngest individuals seen (fig. 1), have a breadth of 1^{mm} and a length of $0{\cdot}66^{mm}$. They represent an early nepionic stage. They are markedly transverse,

* For a classification of the stages of growth and decline as applied to the Brachiopoda, the reader is referred to Beecher's paper on the Development of the Brachiopoda, this Journal, vol. xliv, 1892, pp. 150–154, pl. i. The substitution of the forms *Neanic*, *Ephebic* and *Gerontic* for *Nealogic*, *Ephebolic* and *Geratologic* is in accordance with present usage. See Hyatt, Phylogeny of an Acquired Characteristic, Proc. Am. Phil. Soc., xxxii, pp. 390–397. See also Proc. Bos. Soc. Nat. Hist., vol. xxvi, pp. 93–108.

† Schlotheim's original description of *Terebratulites* (= *Platystrophia*) *biforatus* is so difficult of access that it is here quoted in full:

having an index* of 1·5, and the greatest breadth about one-third of the way from the beaks to the front margin. The posterior margin (cardinal line) is straight, and the anterior semielliptical. The greatest height is at the beaks, which project slightly beyond the area, but are not incurved. The area is considerably less than the width of the shell at the hinge; and the large foramen is about equally shared by the two valves. At the apex of the ventral foramen is a small callosity. No deltidium was observed.

Ventral valve.—In the initial specimens, this valve, for about half the distance from the beak to the front margin, is without longitudinal markings of any sort; but shows a number of very faint concentric lines. The anterior half of the

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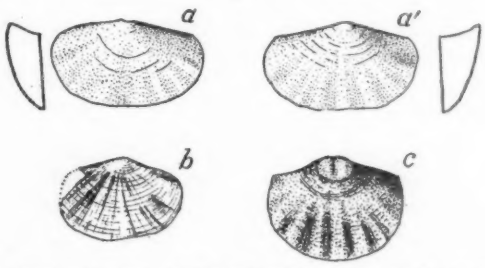

FIG. 1. *a*, Nepionic stage of *Platystrophia*, from specimen obtained at Vevay, Indiana. *a*, dorsal valve, showing median sinus and four plications on either side, profile to left; *a'*, ventral valve showing median fold and four plications on either side, profile to right; ×22. *b*, *c*, *Orthis lenticularis* var. *lyncioides* Matthew; figures of the types: *b*, ventral valve of a transverse individual showing bifurcation of several plications toward the anterior margin; *c*, ventral valve of a narrower individual with very strong plications. The umbonal region is exfoliated. *a*, Author's collection.

valve is thrown into nine low rounded plications. One of these occupies the median line, originates nearer the apex, and is slightly more prominent than the others, thus forming a median fold. Toward the front margin the plications are very faintly crenulated by obscure concentric lines.

"22. Terebratulites biforatus

"Ein freyes ganz vollständig, mit versteinerter Schaale erhaltenes Exemplar, aus dem südlichen Frankreich. Vielleicht gleichfalls aus Kreide-lagern der Champagne. (1 ex.)

"Mit ganz gleichen, breiten, länglichrunden Halften, deren Schnäbel gleichförmig gewölbt und auf beyden Seiten durchbohrt sind. Die Oberschaale mit einer breiten concaven Rückenfursche, die untere Hälfte mit convex hervorstehenden Rücken. Beyde Hälften gleichförmig der länge nach gestreift, mit ziemlich tiefen zwischenfurschen. Ausserordentlich selten."

Die Petrefactenkunde auf ihrem jetzigen Standpunkte, etc., Gotha, 1820, p. 265.

No figure is given.

* Breadth divided by length = shell index.

Dorsal valve.—As in the ventral valve the posterior half is smooth, with faint concentric lines. The anterior half is occupied by eight plications. The depression (sulcus) between the two inner ones is deeper and broader than between the others, giving the effect of a median sinus corresponding to the large median plication or fold of the ventral valve. The convexity of the dorsal valve is nearly as great as that of the ventral.

Comparison with nepionic stages of other Orthidæ.—At the stage represented by the youngest specimens of *Platystrophia* (1^{mm} broad), *Dalmanella (testudinaria, elegantula)* and *Rhipidomella hybrida** have twelve plications on each valve, which arise very close to the apex. The valves are convex, though the dorsal usually has a sinus (sometimes conspicuous) toward the front. The areas are high and well developed, not, however, extending to the cardinal extremities. The ventral area is noticeably higher than the dorsal. The delthyria in both valves are large and open.

Bilobites at this stage has nine plications on the ventral valve, one of which lies at the bottom of a shallow median sinus. These originate, as in *Platystrophia*, about half-way from the beaks to the front margin. The areas are high and the delthyria large and open. The relative convexity of the two valves is almost exactly the same as in *Platystrophia*.†

Hebertella at 1·4^{mm}, the youngest stage yet seen, has eighteen plications which originate very near the beak. The valves are both convex, the ventral being considerably higher. The areas are high and about perpendicular to the plane of separation of the valves.

All the young *Orthidæ* seen, with the exception of *Bilobites*, have noticeably transverse shells:‡ but in all other respects, except the index, the young *Bilobites* most closely resembles the nepionic *Platystrophia*.

Comparison with adult stages of other Orthidæ.—There are no adult *Orthidæ* in the Ordovician with which it is possible to compare the nepionic shell of *Platystrophia*.§ Wysogorski has suggested the derivation of the genus from the *Orthis calligramma* group.‖ His views are based entirely upon adult characters of both groups. He says (loc. cit.) "In both groups the

* For the development of *Dalmanella elegantula* and *Rhipidomella hybrida* see Beecher and Clarke, Mem. N.Y. State Museum, i, 1889, pp. 13–18.

† For the development of *Bilobites*, see Beecher, this Jour. xlii, July, 1891, pp. 51–56.

‡ The index of *Dalmanella* is 1·33 or more, and of *Hebertella* 1·43. That of *Bilobites* is only 1·13 (Beecher's figures).

§ *Orthis lapworthi* Davidson, from the Llandeilo—Middle Caradoc of England, comes the nearest, and is probably an almost lineal descendant of *Orthis lenticularis* of the Upper Cambrian.

‖ Zur Entwicklungsgeschichte der Brachiopodenfamilie der Orthiden im ostbaltischen Silur. Sonder-Abdruck aus der Zeitschrift d. Deut. Geol. Ges. Jahrg., 1900, Heft 2, p. 14.

muscular impressions are the same; many individuals of the *Orthis calligramma* group manifest a tendency to form a sinus, which in *Platystrophia* is so strongly developed that with the corresponding fold of the dorsal valve it constitutes a chief characteristic of this subgenus." It is only necessary to state that the presence of a sinus in the ventral valve of adult Brachiopoda is so nearly universal as to be of little use in tracing phylogenies. As a matter of fact the *nepionic* shell of *Platystrophia* has the sinus in the *dorsal* valve and the fold on the *ventral*. Though this feature also characterizes many specimens of *O. calligramma*, nevertheless the fact that a dorsal sinus is a nepionic feature of such widely separated forms as *Dalmanella*, *Rhynchonella*, *Rhynchotreta*, *Rhynchospira*, *Cœlospira*, *Atrypa*, etc., renders this character of little significance in indicating a common origin of *O. calligramma* and *Platystrophia*.

The ancestors of *Platystrophia* are scarcely to be sought in the Ordovician, since the genus is already represented in the lower beds of this system.* In the Upper Cambrian, however, we meet with a form that possesses in the adult practically all of the nepionic characters of *Platystrophia*. This form is *Orthis lenticularis* Wahlenberg sp., a widely distributed and highly variable species, found in the Lingula-flags of Wales, the Alum schists of Scandinavia, and the equivalent formations of Canada.† Through the kindness of Dr. G. F. Matthew I have obtained for examination the types of his var. *lyncioides* of this species, from the Upper Cambrian of St. John, N. B. These are shown in fig. 1, *b* and *c*.‡ The contour of fig. 1*b* is precisely

* *Platsytrophia* has several times been stated to occur in the Chazy of this country, (see Hall and Clarke, Pal. N. Y., viii, pt. i, p. 202.—Winchell and Schuchert, Geol. Minnesota, iii, pp. 456, 457.—Schuchert, Bull. U. S. G. S., No. 87, p. 309; Proc. U. S. National Museum, vol. xxii, 1900, p. 151 (Birdseye).—Ruedemann, Bull. N. Y. State Museum, No. 49, Dec., 1901, p. 92). I am unable to find any original reference in the literature to its occurrence in rocks of this age. Messrs. Ami, Whiteaves, and W. Billings of Ottawa, Canada, inform me that the museum of the Canadian Survey contains no Chazy specimens; and that they are not aware that the species has ever been found in that series. Mr. Billings suggests that it may have been found in rocks formerly held as Chazy, but now known to be of later age. Mr. McBride of Montreal writes that there are no Chazy specimens in the museums at Montreal and that he does not know of the occurrence of *Platystrophia* in the Chazy. Mr. Seely, who is familiar with the Chazy, writes to the same effect. It is very probable therefore that the form is not known to occur below the Trenton in this county.

† For synonomy and descriptions of this species see Davidson, Silurian Brachiopoda, 1869, pp. 230–232:—Matthew, Trans. Roy. Soc., Canada, ix, 1891, Sec. iv. pp. 46–49. Wysogorski (Entwicklungsgeschichte, p. 8, footnote 1) places *O. lenticularis* in the genus *Orthis* emend. Wysog., which includes the impunctate *Orthidæ*.

‡ These two specimens are figured by Matthew (op. cit., pl. xii, fig. 10). His fig. 10*b* represents the same individual as our fig. 1*b*. It should be noted that all the plications reach the front margin and several of them bifurcate, giving, as shown in our figure, several additional plications at that point.

like that of the nepionic *Platystrophia* (fig. 1*a'*)—a ventral valve in both cases. *O. lyncioides* also has a strong median plication and about four weaker ones on either side. The posterior half of the valve is devoid of longitudinal markings, but possesses concentric lines. The beak is well elevated, though the area is not exposed in any of Dr. Matthew's specimens. As shown in Davidson's figures of *O. lenticularis* the area is high and the foramen large and triangular.* Our fig. 1*c* indicates that the ventral muscular impression is about the same as in other primitive *Orthidæ* (*Platystrophia*, *Plectorthis*, etc.).

The name which Dr. Matthew has given this pretty little variety of *Orthis lenticularis* indicates, as he also expressly states, that he considered it as a possible ancestor of *Platystrophia*. My own conclusion to the same effect was reached independently through a comparison of the nepionic *Platy-*

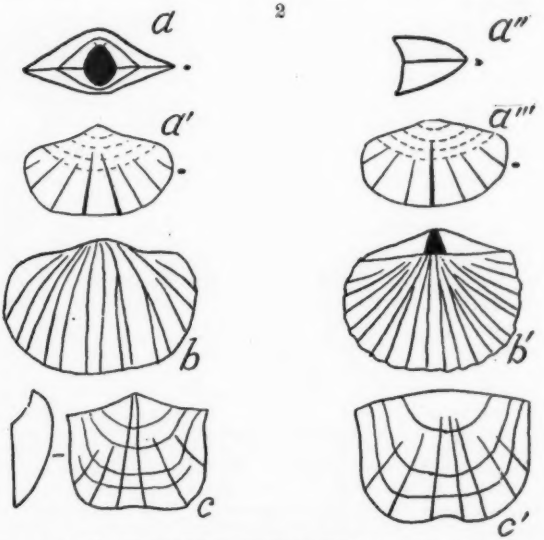

FIG 2. *a*, *a'*, *a''*, *a'''*, posterior, ventral, profile and dorsal outline views of the nepionic *Platystrophia;* actual size shown by small figures to the right. *b*, *b'*, ventral and dorsal views of *Orthis Hicksii*, after Davidson. *c*, *c'*, ventral and dorsal views of *Orthis salemensis*, after Walcott.

strophia with Davidson's figures of *O. lenticularis*. Aside from the strong resemblances pointed out above, the wide distribution, great abundance, and high variability of this species make it an ideal ancestral type. It may very well have produced, on the one hand, the pauciplicate group, *Platystrophia*,

* Silurian Brachiopoda, 1869, pl. xxxiii, fig. 26a.

Orthis s. s. *Dinorthis*, *Plectorthis*, etc.; and on the other the multiplicate group *Hebertella*, *Dalmanella*, etc.

In the Middle Cambrian, *Orthis Hicksii* Salter,* fig. 2*b*, has many of the nepionic characters of *Platystrophia* and may be the ancestor of *Orthis lenticularis*.

The Lower Cambrian furnishes very few Brachiopods of an Orthid aspect: but *O. salemensis* Walcott,† an outline figure of which is given here (fig. 2*c*), again strongly suggests the nepionic shell of *Platystrophia*. In the present state of our knowledge of Cambrian forms it is perhaps unsafe to speculate far in regard to phylogenies of any sort; nevertheless I am inclined to believe that some such form as *O. salemensis* constitutes the final link between the *Orthidæ* and the primitive Brachiopoda of the type of *Kutorgina cingulata*.

II. *Neanic stages.*—The specific characters of *Platystrophia* do not begin to appear until the shell has reached a breadth of 3^{mm} or more. At about this size, the demarcation of the true fold and sinus, which began at a little over 2^{mm}, has produced a noticeable sinuosity of the margin (as viewed from the front). At the bottom of the sinus is a single plication—the same that formed the ventral fold of the nepionic shell. On either side of the sinus are four or five plications (including the ones immediately bounding it). The dorsal valve has the two median plications slightly elevated, forming a fold; and the sulcus between them represents the continuation of the median dorsal sinus of the nepionic shell. (These stages are shown in fig. 3, IV, V.)

A little later (fig. 3, VI), usually at about the breadth of 4^{mm}, two additional plications make their appearance in the sinus at its front margin, one on either side of the primary plication. In the dorsal valve at this stage the two plications of the fold are each seen to bifurcate, giving four in all. The typical number of plications of the fold and sinus of *P. lynx* are now present, though the lateral slopes still possess only five or six. Further increase in the number of plications of the slopes takes place by addition at the cardinal angles, and never (with the rarest exceptions) by bifurcation of those already formed, or by implantation between them. In a shell of 6 or 7^{mm} breadth it is usually possible to determine the variety, therefore the neanic period may be said to cease at that size.

In well preserved material it is possible to study the neanic stages at the beaks of adult specimens; and these stages and those immediately following (early ephebic) are of the utmost importance in tracing lines of descent within the genus. Three

*Davidson, Silurian Brachiopoda, 1869, p. 230.

†Tenth Ann. Rep., U. S. G. S., 1891, p. 612, pl. 72, fig. 6.

of the species which are here recognized as belonging to *Platystrophia* are marked by important differences at this stage.

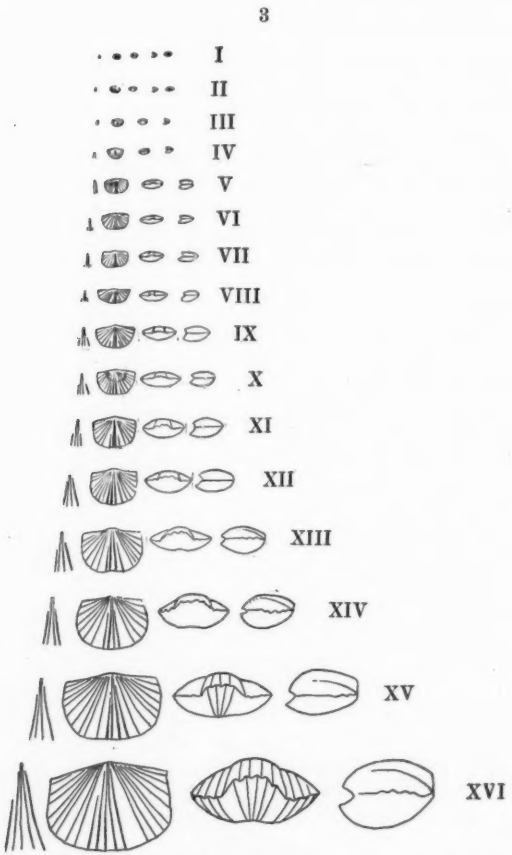

FIG. 3. Series of specimens of *Platystrophia lynx* from Vevay, Indiana, showing change in contour, profile, and convexity of shell with advancing growth. I, specimen 1mm broad, nepionic stage, natural size, same specimen as fig. 1*a*. V, beginning of neanic stage, in which the dorsal fold and ventral sinus become defined. The early ephebic stages are represented by numbers XI to XVI, the latter being a nearly adult individual, possessing four plications in the sinus. The method of origin of the plications of the sinus is shown to the left of each row. All natural size. Author's collection.*

*In all the outline figures in this paper *the lines correspond to the depressions between plications*, and the *interspaces to the plications* themselves.

The above described mode of origin of the plications of the fold and sinus applies to all American Ordovician forms, with the exception of some from the basal Trenton. It does not apply to Upper Silurian forms nor does it seem to apply to Ordovician forms of the Russian Province. Though I have not been able to obtain specimens of Upper Silurian forms of *Platystrophia* in the nepionic stage, nevertheless several adult individuals from the Island of Gotland are so perfectly preserved that even the nepionic stages can be studied at the beaks. In the Gotland specimens, precisely as in the Ordovician specimens just described, there is at first a median ventral fold and a median dorsal sinus. A little later the ventral fold becomes depressed between the two adjacent plications of the valve, and this median plication of the ventral sinus thus formed, immediately bifurcates, making the two main plications of the sinus of all Upper Silurian forms. On the dorsal valve the two plications bounding the median sinus become elevated, and a third is implanted between them, making the three main plications of the dorsal fold of all Upper Silurian forms. All the Russian Ordovician forms studied also belong to this type, as will be shown in a later paragraph.

An examination of thousands of specimens of American Ordovician forms, and scores of specimens of Silurian forms reveals no real exception to the above described modes of origin of the plications of the fold and sinus.* Yet some confusion seems to exist on this very point.

In the Geology of Minnesota, vol. iii, p. 456, occurs the following statement in regard to the development of *Platystrophia:* "The writers [Winchell and Schuchert] regret their inability to secure very young specimens of this species for the purpose of determining the ancestors or line of development. In several immature individuals it has been observed that in the early nealogic [neanic] stage the beaks are strongly elevated, probably erect, and each has a very large open delthyrium, surface smooth at first, but gradually developing eight plications and a mesial sinus in each valve. The sinus in the dorsal valve is bounded by two elevations which become plications, and between them is soon developed a single costa which immediately bifurcates. The four plications increase in strength and become strongly elevated as they proceed to the anterior margin, producing the conspicuous fold of the valve."

With the first part of this statement my observations are in full accord. In regard to the origin of the plications,

* Some specimens from the basal Trenton, to be described later, are of the Upper Silurian type.

however, it is necessary to state that the method they describe has only been observed in an occasional specimen of Upper Silurian (biplicate)* type and therefore does not apply to any of our Ordovician *Platystrophias* above the basal Trenton. In no case have I seen a mesial sinus in both valves, at any stage in development. The true method of origin of the plications in American Ordovician forms was pointed out by Hall in 1847.†

It remains to note some apparent exceptions to the above rule in regard to American Ordovician forms. Very rarely in the Cincinnati group an individual of *Platystrophia costata*‡ occurs with three full plications on the fold and two in the

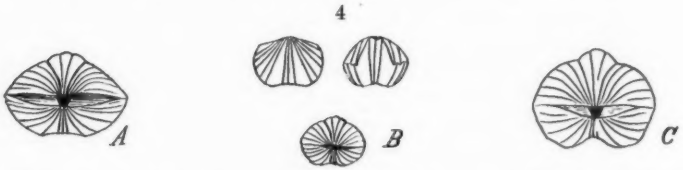

FIG. 4. *A* and *C*, specimens of a pauciplicate *lynx* from Cincinnati, Ohio, in which the third plication of the sinus is suppressed, causing the shell to simulate *P. dentata*, shown at *B*. In *C* the lateral plication of the sinus is clearly seen to be implanted; and less clearly though just as certainly in *A*. In *P. dentata* as shown in *B* (a specimen from Russia) the primary plication of the sinus bifurcates. *A* and *C* from the Dyer collection, Museum of Comparative Zoology, Harvard University. *B* from collection of the U. S. National Museum.

sinus. In the Dyer collection at Harvard, which contains several thousand specimens of this variety, I noticed perhaps half a dozen such individuals. In the majority of these the type is manifestly triplicate, since the second plication of the sinus is implanted at the side of the primary and does not originate by the bifurcation of the primary. The third plication is simply suppressed. I saw but two individuals (fig. 4, *A* and *C*) in which the primary plication seemed to bifurcate, and even here a close inspection of the beak shows that the second plication is really implanted.

Another apparent exception is that of the type in which there is but one plication in the sinus. A careful examination

* It is convenient to speak of forms of *Platystrophia* having *two main plications* in the sinus, originating as just described the Silurian type, as *biplicate*. Those having *three* characteristic plications, as in nearly all American Ordovician forms, are similarly called *triplicate*; and those having but *one* plication in the sinus, *uniplicate*.

† Pal. N. Y., vol. i, 1847, pp. 133-134.

‡ The American form known as *dentata* Meek, and *crassa* James, has been shown to be the same as *costata* Pander. See this Journal, July, 1902, p. 14, footnote.

of numerous individuals has, however, demonstrated the fact that even this type is fundamentally triplicate.* The details of this point will appear later. Suffice it to say that here again the secondary plications have been suppressed. They may often be seen more or less distinctly in the rostral region, but fade out toward the front. With the one exception, therefore, noted above, all the Ordovician forms of this country belong fundamentally to the triplicate type.

Comparison with adult stages of other Orthidæ.—The early neanic shell with one plication in the sinus and five on each lateral slope is strikingly suggestive of the var. *costata* of Russia and the lower part of the Cincinnati group of this country. As just pointed out, however, the latter is evidently derived from a triplicate type such as we find abundantly represented in the Trenton. Practically any group of *Platystrophia* may produce an occasional uniplicate individual. Fig. 15*f* shows it in the normal *costata;* fig. 15*a* in the var. *laticosta.* In the *lynx* group it is extremely rare. Only one example has come to my notice. Theoretically there should be a uniplicate *Platystrophia* in the lowest Ordovician. If this stage was passed before any definite differentiation of the fold and sinus took place, then some of the small *Orthidæ* of the Calciferous and Chazy come very near the requirements. Otherwise I know of no form corresponding to the theoretical uniplicate type.†

In some respects the adult *Plectorthis plicatella* resembles the neanic *Platystrophia.* If the sinus and fold be disregarded (and in some Trenton forms these are surprisingly inconspicuous), the neanic *Platystrophia* is almost a *Plectorthis.* There is little doubt that when the nepionic shell of *Plectorthis* is discovered it will be found to be quite indistinguishable from the nepionic shell of *Platystrophia,* since the two groups present at the beaks almost identical characters. *Plectorthis* appears in American faunas in the Black River formation,‡ and *Platystrophia,* as we have seen, in the basal Trenton. *Plectorthis* may therefore represent an offshoot from the *Platystrophia* group near its initiation or, as sug-

* For the uniplicate European forms I cannot speak. From what I can infer from a careful study of their range and variation, they also probably sprang from a triplicate or biplicate type. This subject will be discussed more in detail later.

† I have gone over the large collections in the Yale Museum, from Crown Point and other well known localities of Chazy and Calciferous fossils. No doubt the connecting form between *Orthis lenticularis* and *Platystrophia* will come to light when much more complete investigations of these old Ordovician rocks are made.

‡ Mr. P. E. Raymond figures and describes specimens of *Plectorthis plicatella* from the Black River limestone of Crown Point, N. Y. (Bull. Am. Paleontology, No. 14, 1902, p. 38, pl. 19, figs. 5, 6.)

gested above, it may have been separately derived from the *Orthis lenticularis* stock.

III. *Ephebic stages.*—The ephebic stages begin with the assumption of characters of lowest taxonomic rank (varietal) (see fig 3; XI–XVI). During these stages there is no marked change in the number of plications, though these may be added, or in the case of the fold and sinus, subtracted, until the final assumption of gerontic characters. The convexity of the valves increases progressively, and the incurvature of the beaks becomes more and more pronounced. The pedicle often

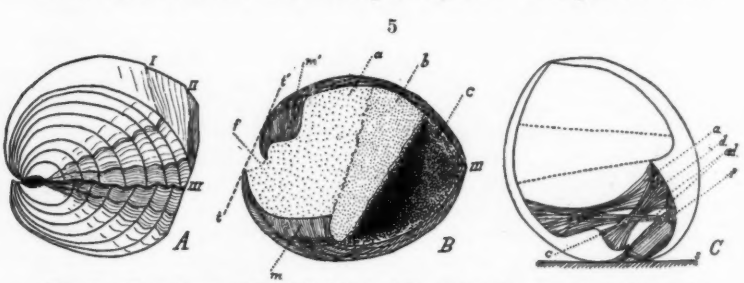

FIG. 5. Very large senile individual of *Platystrophia lynx* from the upper Lorraine of Vevay, Indiana; ×½. *A*, profile; *B* and *C*, sections in the median plane. Normal adult growth was attained at varix No. *I*. The successive additions of shell substance are shown in *B*, and the probable musculature in *C*. The pedicle has entirely abandoned its original foramen and encroaches on the umbonal region of the ventral valve; the apex of the dorsal valve lies in the ventral delthyrium. The shell was partially infilled with very fine silt, probably while still standing in its natural position, with the shell resting on the plane *tt'*(*s*). *f*, pedicle passage; *mm'*, muscular platforms of dorsal and ventral valves respectively; *a*, *b*, oxidized and unoxidized portions of infiltrated material; *c*, cavity lined with small crystals of calcite; *C*, *a.*, adductor muscle; *d.*, diductor; *ad.*, adjustors; *p.*, pedicle; *c*, position of hinge axis. Author's collection.

encroaches on the apex of the ventral valve, even sometimes in early ephebic stages. All, or any of these changes may affect any one of the forms under which *Platystrophia* is known. Other modifications affecting the ephebic stages can more conveniently be discussed under the heads of these various forms.

IV. *Gerontic stages.*—Old age manifests itself in *Platystrophia* by increasing gibbosity, thickening of the shell, pronounced growth varices, and obsolescence of plications, and at times by marked changes in the contour of the shell (shell index). Though senile individuals are met with in all the types of *Platystrophia*, *lynx* and *acutilirata* afford the best examples of it, and in many specimens from the upper range of these species senescence begins early in the ontogeny.

Of these gerontic modifications, the thickening of the shell and obsolescence of plications are the most important. The former character is well shown in fig. 14, and the latter in fig. 12. The thickening of the valves is responsible for the increasing incurvature of the beaks. In extreme cases (fig. 5 *A*) this causes the pedicle to encroach on the ventral beak to such an extent as to completely abandon its normal foramen, which is invaded by the dorsal beak.

Fig. 5 represents the largest specimen of *P. lynx* seen. *C* shows it in its natural position during life with an indication of the musculature. This individual is decidedly senile, complete ephebic growth having terminated at the varix No. *I*, though the amount of thickening of the shell is not as great as in many smaller individuals (cf. fig. 5*B* and fig. 14*B*).

Platystrophia acutilirata presents even more extreme gerontic modifications than *P. lynx*. The greatest gibbosity seen in any group occurs here, and the amount of change in the shell index is truly remarkable. It will be more convenient, however, to discuss the details of these changes due to senescence under the heads of the several species and varities of *Platystrophia*.

*Platystrophia lynx.**

The species commonly known in this country as *Platystrophia lynx* is beyond any question the most abundant and widespread Ordovician member of the genus, and also bears the greatest resemblance to the species commonly known as *Platystrophia biforata* (Schlotheim). Hall† does not attempt to distinguish between them. Davidson‡ says in regard to the British specimens, "We certainly have the type *biforata* and the variety *lynx*, but these two seem so intimately connected that I have combined them under Schlotheim's single designation [*biforata*]." According to von Buch,§ *lynx* has four plications in the sinus and on the fold‖ and nine on each side. Schlotheim's *biforatus*, he says, is "very nearly related" to *lynx*. The former has five plications in the sinus and nine on each side and is broader than *lynx*. According to de Verneuil¶ "The *S.* [*Spirifer*] *biforatus* proper seems to be rare; we have, as had Eichwald, a single specimen very poorly preserved. His came from Reval and ours from the neighbor-

* Eichwald, Skizze von Podolien, 1830, p. 202.

† Pal. N. Y., i, 1847, p. 132.

‡ Silurian Brachiopoda, 1871, p. 271.

§ Essai d'une classification et d'une description des Delthyris, etc., Mem. Soc. Géol. France, iv, 1840, pp. 190, 191.

‖ He certainly was mistaken in either the number on the fold or in the sinus. There is always one more on the fold.

¶ Géol. de la Russie, 1845, pp. 136, 137.

hood of St. Petersburg. The beaks, as in most *Spirifers* from the latter locality, are small, appressed and render it difficult to view the double area" (p. 136). Of *lynx* he says, "This variety differs from *S.* [*Spirifer*] *biforatus* only in the less number of plications in the sinus . . . . . M. Eichwald says he found it in the drift near Grodno, with two plications in the sinus, three on the fold and eleven on the sides" (p. 137).*

So far as concerns the characters mentioned above as distinctive of *lynx* and *biforata*, it must be admitted that none of them are of any value. *Platystrophia lynx* has all the way from one to seven plications in the sinus and may have from six to twelve on either side; and varies in shell index between the limits of 1·0 and 1·8.†

It is altogether likely that the *biforatus* type does not occur in American upper Ordovician faunas; and the same may be true of Eichwald's species, *lynx*. The latter certainly and Schlotheim's species in all probability, came from Russia. In regard to *biforatus*, von Buch (loc. cit.) says, it "very likely came from the north and not from France." With our present knowledge of the species we may be sure it did not come from France, at least, if it is an Ordovician type at all. It may very likely have been obtained in the same manner as *P. lynx* from glacial pebbles.‡

I have before me specimens of the *lynx*, *biforata*, and *dentata* types from the Ordovician of Russia. All of these show a peculiarity that I have never seen in an American so-called *biforatus* or *lynx*, from beds of equivalent age, namely, the presence at the beaks of three plications on the fold and two in the sinus. This peculiarity, as has been pointed out, invariably characterizes Silurian forms both American and foreign.§

Figures 6, 4*b* and 21*e*, are of these Russian types; and show the number and arrangement of the plications of the fold and sinus. Fig. 21*e*, of the ventral valve of a specimen of *P.*

* The shell index of *biforatus* given by deVerneuil is 1·5 : that of *lynx* 1·3.

† Schuchert says (Bull. U. S. G. S. No. 87, 1897, p. 308), "Individuals of a stratum . . . . are fairly constant in form, size, and plications, and it is this limited constancy that has served in many of the following species [*biforata, lynx, laticosta, acutilirata, crassa*]." Even this "limited constancy" can scarcely be found in many localities, for I have seen several of the varieties *together in a single slab of limestone.*

‡ It should be remembered that Schlotheim *distinctly states* that his "one example" of *Terebratulites biforatus* came from Southern France. Either he was mistaken or this type is a Mesozoic *Spiriferina!*

§ Mr. A. F. Foerste (Bull. Dennison University, i, 1885, p. 80) was the first to call attention to the fact that Silurian forms have an odd number of plications on the fold and an even number in the sinus, while the reverse is true of Ordovician forms. While this is not strictly true, it is true that the Silurian forms have *at the beak*, without exception, three on the fold and two in the sinus.

biforata from Wesenberg,* Russia, shows five plications in the sinus. To the left is shown the arrangement of these plications. At the apex there is a single plication which immediately bifurcates. Then a plication is implanted between the two thus formed, and immediately bifurcates giving four plications. Between the two last formed is now implanted

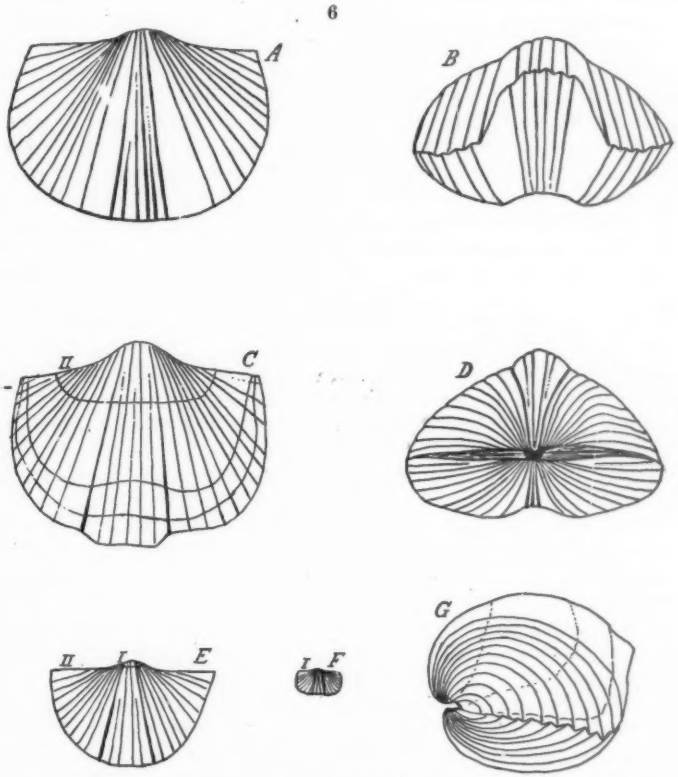

FIG. 6. *Platystrophia biforata* (*P. lynx* of authors) from Pulkowa, Russia. *A–D* ventral, anterior, dorsal, and posterior views; *E*, stage *II.* (see *C*) drawn separately; *F*, stage *I.* (see *E*) drawn separately; *G*, profile, showing strong incurvature and great size of dorsal valve.† Collection U. S. National Museum.

another plication, making five. Fig. 21*e'*, of the dorsal valve of the same specimen, shows six plications on the fold, which as seen in the diagram to the left originate as follows: first, two

*This specimen and the next to be described were labeled by F. Roemer.
† All figures natural size unless otherwise stated.

appear at the apex; between these, one is implanted and almost immediately bifurcates; and between these two, another is implanted and bifurcates, making six in all.

Another specimen of *P. biforata* from Wesenberg, Russia, has four plications in the sinus and five on the fold, but they originate in precisely the same way. The last plication added on the fold does not, however, bifurcate; and the unpaired median plication of the sinus is wanting.

In a specimen from Pulkowa, Russia (near St. Petersburg), labeled *P. lynx*, there are (fig. 6) six plications on the fold and five in the sinus. These originate as follows: In the sinus one plication appears at the apex and immediately bifurcates. Each of the two thus formed bifurcate, and the one to the left bifurcates again, giving five in all. On the fold two plications appear at the apex and one more is almost immediately implanted between them. Each of these three now bifurcate, giving, at the front margin, six plications. The specimen therefore belongs to the same type (biplicate) as the Wesenberg specimens. It is impossible to make sure from the literature of the Russian *Platystrophia* whether this peculiarity characterizes all Russian forms. According to Wysogorski,* who is very familiar with the *Orthidæ* of the Baltic-Province, "the form from the Upper Silurian of Gotland is characterized by smaller size [than the Russian form] while in other respects it agrees with *Platystrophia biforata* Schloth." I have examined some thirty specimens of the Gotland form and these invariably have three plications on the fold and two in the sinus. If Wysogorski has taken this peculiarity into consideration, his statement is strong evidence, in support of that afforded by the Russian specimens which I have examined, as to the biplicate character of all these Russian types. None of the earlier authors shed any light on this point. De Verneuil gives several excellent figures of the *lynx*, *dentata* and *chama* (=*costata*) types and mentions a *lynx* from Grodno with two plications in the sinus. In his figures of *lynx* four plications are shown on the fold but their mode of origin cannot be made out, though they are all shown to originate closer to the apex than is common in our American *lynx*, and even closer than in the *lynx* from Cincinnati, Ohio, figured on the same plate. Whenever four plications are present on the fold of biplicate types, they certainly come in closer to the apex than the four plications of triplicate types. Nevertheless, such evidence as afforded by the figures in question cannot be considered as of any particular value.

Davidson's figures and descriptions of British Ordovician

* Entwicklungsgeschichte, p. 15.

specimens leave us almost equally in the dark on this point.* Fig. 12 of *biforata* certainly seems to be of the triplicate type, the same as our Trenton and Cincinnati *lynx*. The var. *fissicostata*, on the other hand, is more probably of the biplicate type; as are certainly all the Wenlock forms figured. On the whole, it seems quite likely that the majority of Russian, if not of all European Ordovician forms of *Platystrophia*, belong to the biplicate type. *In this country, however, the biplicate type is absolutely restricted to the Silurian and basal Trenton.*†

This difference in the mode of origin of the plications of the fold and sinus is of fundamental importance. It has been shown that in nepionic stages of all forms, whether American or European, Ordovician or Silurian, there is a median plication or fold on the ventral valve and a median sulcus or sinus on the dorsal valve. This nepionic ventral fold becomes the primary plication of the ventral sinus of later stages. In triplicate and uniplicate types this primary plication remains simple; but in biplicate types it bifurcates near its point of origin, i. e., in an early neanic stage. Such a difference characterizing so early a stage of the shell certainly *points to the origin of the peculiarity very early in the history of the genus;* and it is consequently very significant that the only place where the two types, biplicate and triplicate, are associated together in American faunas, is in the basal Trenton of the Hudson-Champlain area.‡ The question whether there is a similar association of the two forms in the early Russian deposits cannot with the material at present available be definitely settled.

Platystrophia seems to have made its appearance in Russian seas at fully as early an epoch as in American. Wysogorski states that it occurs first in the Echinosphærites limestone.§ Schmidt lists *P. lynx* from Erras, Reval and Odensholm in beds from the "vaginatum" limestone to the Borkholm.‖ Wl.

* Silurian Brachiopoda, 1871, pp. 268–273, pl. xxxviii, figs. 11–25.

† These basal Trenton forms from the Hudson-Champlain area will be described under the *biforata* type, to which they belong. The fact that they are of the biplicate type, taken in connection with the further fact, brought out by Ruedemann, of the general European aspect of the Lower Ordovician faunas of the Hudson Valley area, is certainly in striking accord with the evidence already adduced as to the predominance of the biplicate type of *Platystrophia* in European faunas. See also Ulrich and Schuchert, Bull. N. Y. Mus. No. 52, 1902, pp. 633–663.

‡ An apparent exception to this statement has been discussed under the subject of neanic stages.

§ Entwicklungsgeschichte, pp. 14, 15.

‖ Untersuchung über die Sil. Form. von Ehstland, etc. Archiv. für die Naturkunde Liv.-, Ehst.- und Kurlands, 1ter ser., 2ter Band, 1858, p. 213.

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Lamansky cites *Platystrophia biforata* from the "planilimbata" limestone.* As to the correlation of these beds with American strata there is unfortunately no unanimity of opinion. Schmidt is disposed to consider the Echinosphærites limestone as the equivalent of the Quebec Group of this country; and the vaginatum as equivalent to our Black River formation.† In Kayser's Lehrbuch der Geologie (1891) the Echinosphærites limestone is placed higher than the Trenton and the vaginatum as equivalent to the Trenton.‡ The planilimbata limestone would then be about equivalent to our Black River. Substantially the same correlation is given by Neumayr§ and by de Lapparent.‖ It seems probable, therefore, that the first appearance of *Platystrophia* in Europe was at least as early as in this country, and perhaps earlier: and since it was during this early Ordovician epoch that the two main types of the genus were being differentiated, we may expect to find both in the European as well as in the American deposits of that age.

From the above discussion it appears that there existed after the early Ordovician two distinct types of *Platystrophia*, one of which (the triplicate) characterized the American Ordovician, and the other (the biplicate) the European Ordovician and the Silurian of both America and Europe. Both of these types or species include several varieties. It is also evident that the terms *lynx* and *biforata* have been very loosely applied to both of these types. Since the term *lynx* has become so strongly associated with the American group of shells (triplicate type), I propose to limit the term to such American Ordovician shells. It is impossible to say whether the type of *P. biforata* is biplicate or triplicate. The presumptions are strongly in favor of its being biplicate. I, therefore, propose to restrict the term to biplicate forms such as the Wesenberg specimen above described. It will then include Ordovician forms of Europe, and Clinton forms of both Europe and America. For the biplicate shells with few plications such as are found in Gotland, the Wenlock of England, and Anticosti, the term *dentata* will be used. Further details of the species *biforata* and *dentata* will be given later.

Derivation of Platystrophia lynx.—According to the above interpretation and restriction of *P. lynx*, this form probably

* Neue Beiträge zur vergleichung des Ost-Baltischen und Scandinavischen Unter-Silurs. Centralblatt für Min. Geol. und Pal., Neues Jahrb., 1901, No. 20, pp. 611–618.

† Quar. Jour. Geol. Soc., xxxviii, 1882, pp. 520, 521; Archiv. Liv.-, Ehst.- und Kurlands, 1ter ser., 2ter Bd., 1858, p. 48.

‡ Op. cit., p. 64.

§ Erdgeschichte, 1895, vol. ii, p. 98.

‖ Traité de Géologie, 1900, p. 824.

stands nearer the radical stock than any other. The case in which the nepionic ventral fold remains simple and unmodified throughout the life of the individual certainly must be considered as more primitive than the case in which the nepionic fold bifurcates. It is known that in nepionic and early neanic stages of brachiopods, plications are added by implanta-

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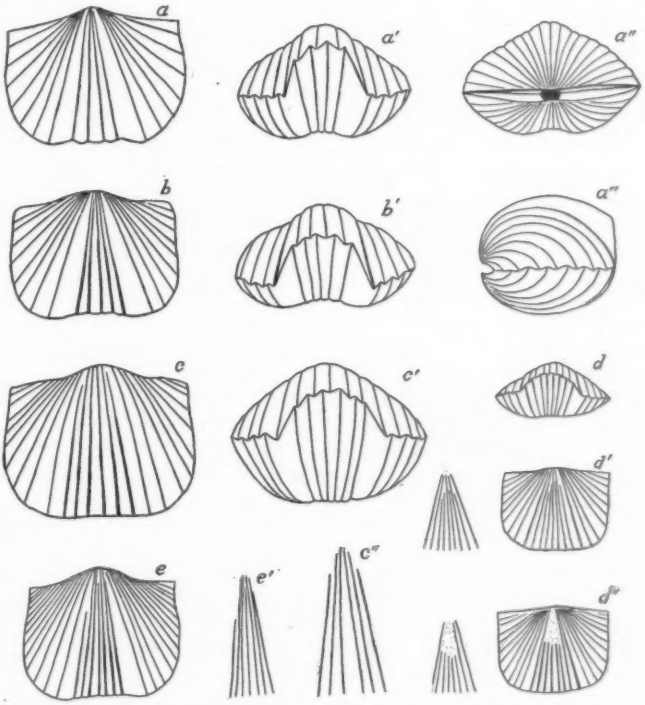

FIG. 7. *Platystrophia lynx* from Vevay, Indiana, showing variation in number of plications of fold and sinus. *a a'''*, ventral, anterior, posterior and profile views of a normal individual with the normal number, three in sinus and four on fold; *bb'*, ventral and anterior views of individual with four plications in sinus, the fourth originating by bifurcation of the left lateral; *cc'*, ventral and anterior views of individual with five plications in sinus, the two additional plications are implanted, *c''*, diagram showing method of origin of plications; *ee'*, individual with six plications in sinus; *dd''* (with diagrams to left of *d'* and *d''*), individual with seven plications in sinus; *d'*, dorsal; *d''*, ventral views. Author's collection.

tion except in highly accelerated types. We must believe, therefore, that a tendency of the primary plication of the

sinus to bifurcate manifested itself as an adult character in the ancestors of *Platystrophia biforata*, and that, subsequently, acceleration crowded back the point of bifurcation into early neanic stages.

The most primitive *Platystrophia* should, as stated in another place, be uniplicate, and it was from such a uniplicate stock that both *P. lynx* and *P. biforata* were derived. The fact that in *lynx* there is no modification of the fold and sinus until an *advanced* neanic stage, while in *biforata* such modification takes place, as explained, at an *early* neanic stage, indicates that *lynx* is nearest to this primitive *Platystrophia*. *P. lynx certainly stands as the radical of all our Ordovician forms above the basal Trenton.*

Variation of Platystrophia lynx.—This subject has already been investigated quantitatively and the results published.* As that investigation applied to specimens from the Middle Cincinnati group only, there is considerable to add in regard to Trenton forms and especially in regard to some highly accelerated forms from immediately beneath the Clinton limestone at Richmond and other localities in Indiana. The Vevay material, quantitatively studied, included the varieties *laticosta* and *costata*, which were shown to pass by insensible gradations into the normal *lynx* type.†

The *lynx* group of the Trenton varies extensively in contour and number of plications, as has often been pointed out.‡ Fig. 8 shows the contour of a series of sixteen specimens, taken at random, from Trenton Falls' material. The index here varies from 1·2 to 1·82, the average being 1·42 and the largest class 1·4. The angle between the hinge line and lateral line of the sheli (cardinal angle) varies from 80° to 110°; the number of plications on the ventral valve from 17 to 24, and the number in the sinus from 2 to 6. No. 32, fig. 8, is a composite of Nos. 1-16 inclusive and shows the normal Trenton Falls' type of shell. This shell has a cardinal angle of 90°, with very slight auriculation.§

* Cumings and Mauck, A Quantitative Study of Variation in the Fossil Brachiopod *Platystrophia lynx*. This Journal, July, 1902, pp. 9-16.

† Mr. F. W. Sardeson has expressed the opinion that all the so-called varieties of *Platystrophia* in the Cincinnati group are distinct.

A careful study and measurement of over 2,000 individuals and inspection of some 8,000 others, has failed to establish a specific distinctness. See Sardeson, Am. Geol., vol. xix, 1897, p. 109. Compare also Williams, Geol. Biology, pp. 315, 321.

‡ See especially Hall, Pal. N. Y., vol. i, 1847, pp. 133, 134. Winchell and Schuchert Geol. Minn., iii. 1893, pp. 456, 457.

§ When there is any auriculation of the cardinal extremity the measurement is made between the hinge line and a line tangent to the cardinal extremity and the lateral margin, as shown in fig. 8 *bis*.

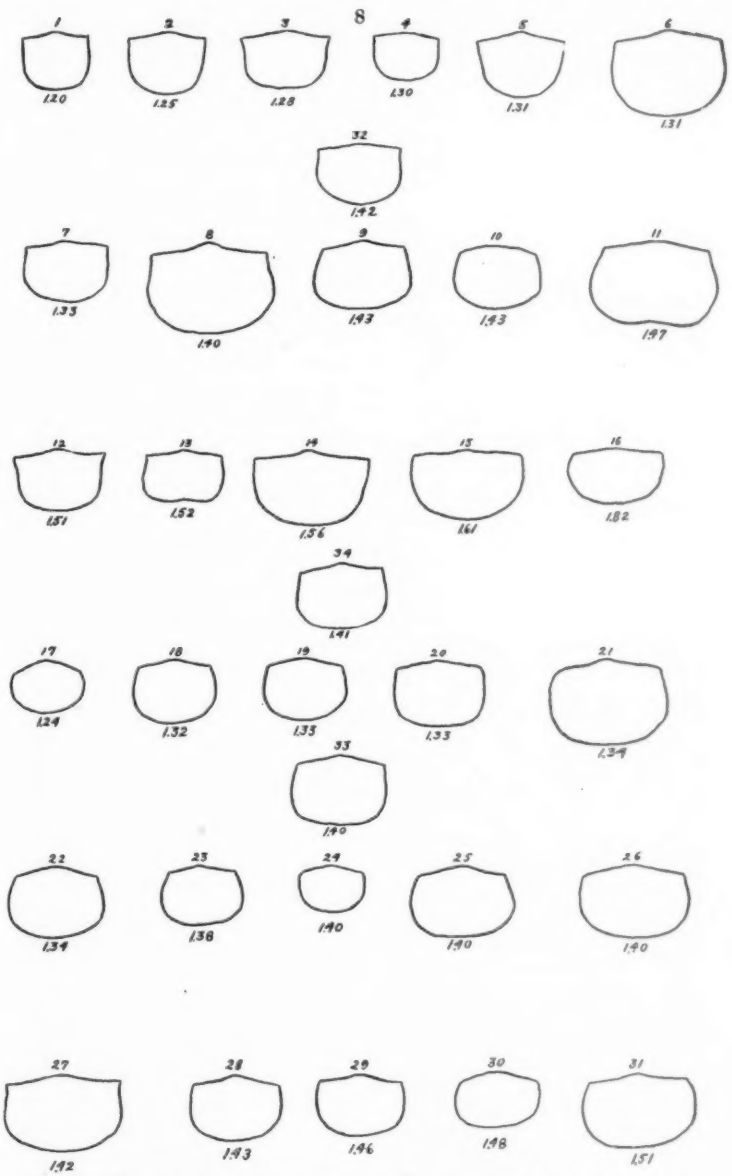

FIG. 8. *Platystrophia lynx.* 1-16, from Trenton Falls, N. Y.; 32, composite of 1-16; 17-31, from Colby County Kentucky (Trenton); 33, composite of 17-31; 34, composite of 1-31; Shell index given below each figure. All natural size. Collection Yale Museum.

Nos. 17-31 inclusive, fig. 8, represents the contours of a series of specimens from the Trenton of Kentucky (Colby Co.). Here the index varies from 1·24 to 1·51; the average being 1·4 and the largest class 1·4. The cardinal angle varies from 90° to 112° (in a specimen from Harrodsburgh, Mercer Co., Ky., the cardinal angle is 120°). The number of plications varies from 17 to 27; the number in the sinus from 3 to 5. No. 33, fig. 8, is a composite of Nos. 17-31 inclusive. This normal shell of the Kentucky group has an index of 1·40 and a cardinal angle of 95°. No. 34, fig. 8, is a composite of Nos. 32 and 33, and has an index of 1·41 and an angle of 93°. The great similarity of the New York and Kentucky forms is apparent.

8 *bis*.

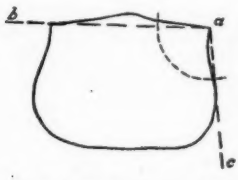

FIG. 8 *bis*. Diagram showing method of obtaining cardinal angle *bac*.

Very few specimens from the Trenton of Minnesota have been studied, but these show no departure from the above type. The specimens from the Galena of Minnesota are however more like the Cincinnati group *lynx*.

In brief, the Trenton shell is rather transverse, slightly shorter on the hinge than farther forward; valves about equally convex, never extremely gibbous; plications about 22, of which three or four are in the sinus, four or five on the fold. The sinus is never as profound as in the varieties *costata*, *laticosta* and *acutilirata*.

The Trenton forms just described are from the middle and upper part of the series. Some specimens from Montreal, Canada, loaned me by Mr. Chas. Schuchert, are of a somewhat different and more primitive type. These latter (fig. 9) have

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FIG. 9. *Platystrophia lynx*, small pauciplicate form from the lower Trenton at Montreal, Canada. *a*, ventral; *b*, anterior; *c*, profile; *d*, posterior views. Schuchert collection.

but 4–7 plications on the slopes; the shell is narrowest at the hinge-line and considerably less transverse than the Trenton Falls type (the index is 1·23 in the specimen figured, which is about an average individual). The second and third plications of the sinus arise about 4^{mm} from the beak. These shells strongly suggest the small pauciplicate form found at the base of the Lorraine at Cincinnati, Ohio.* As to the exact age of the beds from which these specimens came it is impossible to say. In

*See Winchell and Schuchert, Geol. Minn., iii, 1893, p. 456.

the section at Montreal, given in the Geology of Canada, "*Orthis lynx*" is listed from the first, second, and fourth divisions of the section; that is from the lower 150 ft. of the formation. The chances are that the present specimens are from the lowest of these divisions, or less than 10 ft. above the Black River formation.* These small shells may therefore represent the immediate ancestors of the normal Trenton form above described.

The small pauciplicate *P. lynx* (fig. 9 *bis*) from the lower Lorraine at Cincinnati, is of interest as the immediate progenitor of *P. costata* and probably also of *P. laticosta*. It occurs, associated with the uniplicate form *(costata)*, often in clusters, one of which is shown in fig. 9 *bis*. This specimen has the shells in their natural position, with the beaks very closely appressed to the surface of support. The individual at the top of the figure is wedged in so closely between the adjacent branches of the *Constellaria*, as to indicate that the two valves never gaped more than very slightly indeed.

9 *bis*.

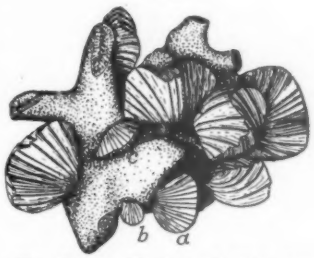

FIG. 9 *bis*. Cluster of *Platystrophia lynx*, pauciplicate form, on a colony of *Constellaria constellata*. All the individuals are in their natural position with the beaks closely appressed to the surface of support. *a* and *c*, *Plectorthis plicatella*; *b*, *Zygospira modesta*. Collection of the Museum of Comparative Zoology, Harvard University.

The question arises whether this form of *P. lynx* is not an unmodified descendant of the Montreal type just described. This is certainly possible if not probable. The occurrence of an occasional individual with few plications among the normal *P. lynx* of the middle and upper Trenton suggests, on the other hand, that these lower Lorraine forms may have originated as a variant of the latter. For convenience this form of *P. lynx* may very well be called *pauciplicata*. It seems, as stated above, to represent the initiation of a tendency that afterwards in *P. laticosta* and *P. costata* assumed considerable importance.

In American literature the Trenton shells have often been referred to the species *biforata*. I have already pointed out the fact that this type is not represented in American Ordovician deposits above the basal Trenton. The large form from the Cincinnati group universally known as *Platystrophia lynx* probably differs from the Russian *lynx* and is identical with our Trenton forms. In the interval between the Trenton and Lorraine the typical *lynx* changed surprisingly little. Fig.

*Geol. of Canada, 1863, pp. 137–138.

10, *a*, is drawn from an individual which departs very little from the normal form of the Lorraine.* Fig. 10, *b*, is an average specimen from Trenton Falls, N. Y., enlarged to the same size. The two shells have the same index, nearly the same number of plications, and differ little in contour. The cardinal angle of the Lorraine specimen is 89°, that of the Trenton Falls specimen 96°. The latter is more gibbous. It would

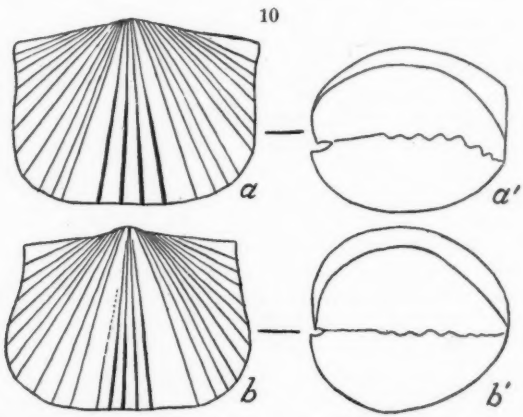

FIG. 10. *Platystrophia lynx*. *aa'*, normal Lorraine type from Vevay, Indiana, natural size; *bb'*, normal Trenton type from Trenton Falls, N. Y.; ×2½. *a*, author's collection; *b*, collection of Mr. Wm. L. Porter.

be possible to select plenty of adult individuals from the Trenton and Lorraine that except for size would present no appreciable differences. The slight change of the average shell index (from 1·4 in the Trenton specimens to 1·3 in the Lorraine (Vevay) specimens) is due solely to the more robust growth of the latter, which always have the higher index in early ephebic stages (see fig. 13). It will be shown later that the extreme manifestation of this tendency produces in the upper Lorraine a shell of very low index; while the latest representatives of *lynx*, now to be described, have again a very high index.

In the extreme upper part of the Ordovician (Madison beds) of Richmond, Weisburg and Laurel, Indiana, the writer found a variety of *Platystrophia lynx* which is of exceptional interest (fig. 11). As is well known, the so-called Richmond beds (*Rhynchotrema* zone) contain exclusively the variety *acutilirata* associated almost constantly with *Hebertella occidentalis*. At about 50 ft. below the Clinton at Laurel and about 13 ft.

* This specimen is from Vevay, Indiana.

to 15 ft. at Richmond, comes in a large and decidedly transverse variety of *P. lynx* associated with *Hebertella sinuata*.* This association is a point of great importance since it shows that these two forms of *Platystrophia* and *Hebertella*, so constantly met with together in the Lorraine, have lived on together at some point through the *Rhynchotrema* hemera† and here under a recurrence of suitable conditions reappear, the former with some modification, the latter with scarcely any.‡

This form of *Platystrophia lynx* has eight to eleven plications on the lateral slopes, and the index may be as great as 1·9.

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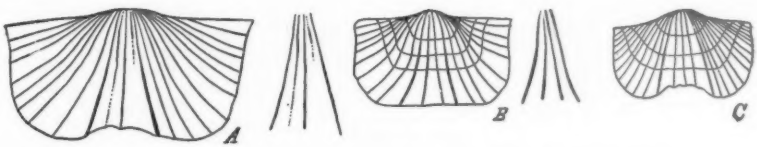

FIG. 11. *A*, *Platystrophia lynx* from 12 ft. below the Clinton at Richmond, Indiana; dorsal valve showing obsolescence of both lateral plications toward the anterior margin. *B*, dorsal valve of another individual from the same horizon and locality showing complete reduction of the fourth plication. *C*, specimen of *P. acutilirata* from the extreme Upper Ordovician at Weisburg, Indiana, showing the similarity of this retrogressive form to *P. lynx*. Author's collection.

A number of individuals (5 out of 100) show a reduction of the lateral plications of the fold and sinus. Fig. 11, *A*, shows a reduction of both lateral plications of the fold. On the anterior portion of the fold, the one to the right has completely vanished and the one to the left is very faint and does not reach the margin. All four plications are about normal on the posterior portion of the fold. Another specimen, fig. 11, *B*, has three plications on the fold. The only indication of the fourth is the abnormal breadth of the right hand plication at the umbonal region.

That such a tendency to eliminate plications should affect 5 individuals out of 100, while in the Lorraine not more than one *P. lynx* out of a thousand exhibits anything analogous, is certainly not without profound significance. There are in the

* These beds are exposed at Richmond near the point where the "Boston Pike" crosses Elkhorn Creek, S.E. of the city. The ledge of Clinton 12 ft. thick forms a fall. Immediately below the Clinton is 4 ft. of clay and below this, limestone layers alternating with shale. *Platystrophia lynx* is found in large numbers in the limestone for some distance down the creek.

† Buckman's term, or some other equally unequivocal, is needed in a case like this where the lifetime of a species is referred to. See Quar. Jour. Geol. Soc., xlix, 1893, p. 481.

‡ The Rhynchotrema zone does not contain any specimens of *Hebertella sinuata* except at its very base.

present collection two specimens of *Platystrophia lynx* from Vevay, Indiana, both of which have three plications on the fold: One individual has four in the umbonal region; and the other never developed but three* at any stage. The first has an abnormally low index (1·1) and bears every evidence of lateral cramping during growth. This would account for the failure

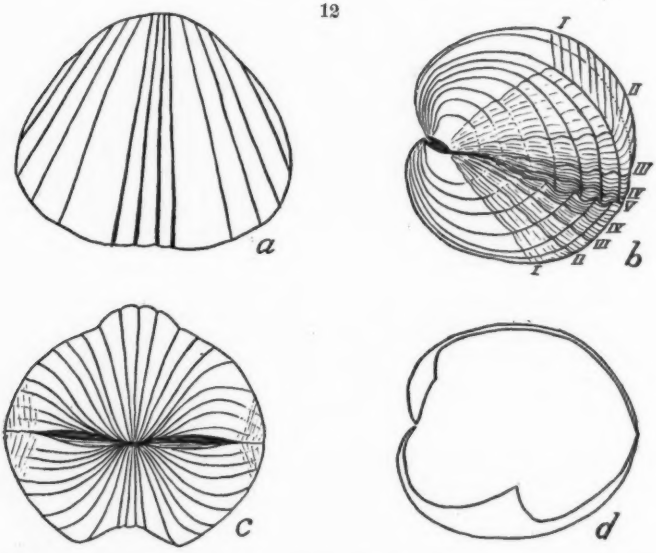

FIG. 12. Markedly gerontic individual of *Platystrophia lynx* from the "lynx beds" of Cincinnati, Ohio. Normal adult growth ceased at varix No. *I*. Note the very large cardinal angle (125°), extreme gibbosity, and obsolescence of the lateral plications. Dyer collection, Museum of Comparative Zoology, Harvard University.

of the fourth plication. The early growth stages of the second specimen also show an abnormally low index and the failure to develop the full number of plications is therefore probably due to the same cause. The Richmond shells, on the other hand, are very transverse at all stages, especially so in the adult. The correct explanation of the obsolescence of plications in this type, as well as in the *laticosta* and *costata* types where it is still more pronounced, is probably to be sought in a readjustment of the brachia, producing an elevation and narrowing of the fold. This subject will be more fully discussed in a later paragraph.

* Both are strictly of the triplicate type.

Gerontic stages of Platystrophia lynx.—The gerontic stages of this species are alluded to above. In the "lynx beds"* at Cincinnati, Ohio, there is a veritable race of gerontic individuals. Fig. 12 represents one of these (from the Dyer collection of Harvard). The hinge-line is relatively very short, the cardinal angle being 125°. The vertical diameter exceeds the longitudinal in the ratio of 102 to 100. The shell index is 1·16; so that the three dimensions of length, breadth, and height are nearly equal. This extreme gibbosity, combined with so short a hinge-line, produces the peculiar effect seen in fig. 12, *a*; that is, though a similar view of *P. lynx* usually shows all the plications of the slopes, in this case only five out of eight are visible on each slope. Normal adult growth was reached at the varix numbered *II*. After this point the increase was mainly in a direction at right angles to the plane of separation of the valves. This has produced such a degree of incurvature of the beaks that the delthyria are completely concealed, and since there is in this individual no encroachment of the pedicle upon the ventral beak, this organ must have been reduced to very small dimensions or possibly have ceased to function at all. The changing contour of another individual, in which gerontic stages are initiated early in the ontogeny, is shown in fig. 13, of a specimen from Vevay, Indiana. *b–g* show these successive stages separately drawn.

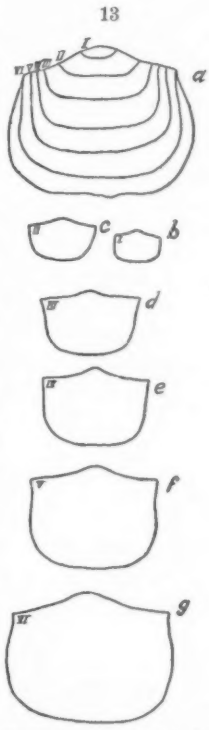

FIG. 13. *Platystrophia lynx* from the upper Lorraine, Vevay, Indiana, showing growth varices (*I–VI*) of a gerontic individual and the successive stages drawn separately (*b–g*). Author's collection.

The initiation of gerontic stages early in ontogeny is clearly indicative of the paracme of this type of *Platystrophia*. One of the most extreme manifestations of senescence is the obsolescence of the plications; yet in the present group this begins comparatively early (fig. 12, *b I*) and in later stages the 1st, 2d, 3d and 4th plications from the cardinal angle have completely disappeared and the shell is non-plicate, except at the front margin; and even here the plications are inconspicu-

* See Nickles, Jour. Cin. Soc. Nat. Hist., vol. xx, No. 2, Jan. 1902, pp. 85, 86.

ous. Another feature indicative of extreme senescence is the thickening of the shell. This has advanced to such an extent in many specimens from the "lynx beds" that the space available for the lodgment of the internal organs of the animal is less than in earlier growth stages. In one specimen, fig. 14, *C*, there is a very exceptional thickening of the ventral valve over the anterior margin of the ovarian region. In all cases of great thickening of the shell the muscular pit of the ventral valve is profound and the shell substance at its bottom is often so thin as to be translucent. Fig. 14, *B*, shows one of the most massive shells seen. This shell is 12^{mm} thick at the anterior rim of the muscular pit. Six laminæ parallel to the outer surface of the shell (corresponding to as many strong growth varices) indicate the successive additions to the shell substance. After the first (lowest) of these no forward growth took place, and there was a progressive reduction in the amount of room inside the shell.

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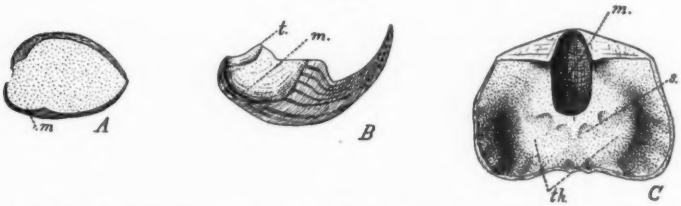

FIG. 14. *Platystrophia lynx*. *A*, from Vevay, Indiana; *B* and *C*, from Cincinnati, Ohio, all slightly reduced. *A*, normal adult individual cut anteroposteriorly in the median plane to show normal thickness of valves; *m*, muscular platform of ventral valve. *B*, extremely senile and greatly thickened ventral valve, showing lamination of shell substance and six successive additions on its inner surface after normal adult growth had been attained; *t*, tooth; *m*, muscular pit; *C*, greatly thickened ventral valve, interior view showing profound muscular pit, *m*; vascular impressions, *s*; and abnormal thickening in the ovarian region, *th*. *A*, author's collection; *B*, collection of Yale Museum; *C*, Dyer Collection, Museum of Comparative Zoology, Harvard University.

There is no evidence that this gerontic type of *lynx* extended its range beyond the "lynx beds," or that it produced any radical from which a new orthid stock sprang. It seems to have become extinct. The succession, so far as concerns the remain-

FIG. 15. *a-e*, *Platystrophia lynx var. laticosta* from the Lorraine, Vevay, Indiana. *a-a'''*, anterior, ventral, posterior, and profile views of the form *unicostata*, in which the lateral plications of the fold and sinus are completely lost; *b-b'''*, same of an individual which has one lateral plication feebly developed; *c-c'''*, same of an individual in which the lateral plications of fold and sinus are present only in the umbonal region; *d-d'''*, individual with one complete lateral plication; *e-e'''*, normal *laticosta* type. *f-f'*, tracing from Pander's figure of *P. costata*; *g-g'*, tracing from Meek's figure of *P. dentata*; *h-h'*, tracing from deVerneuil's figure of *P. chama*. *a-e*, author's collection.

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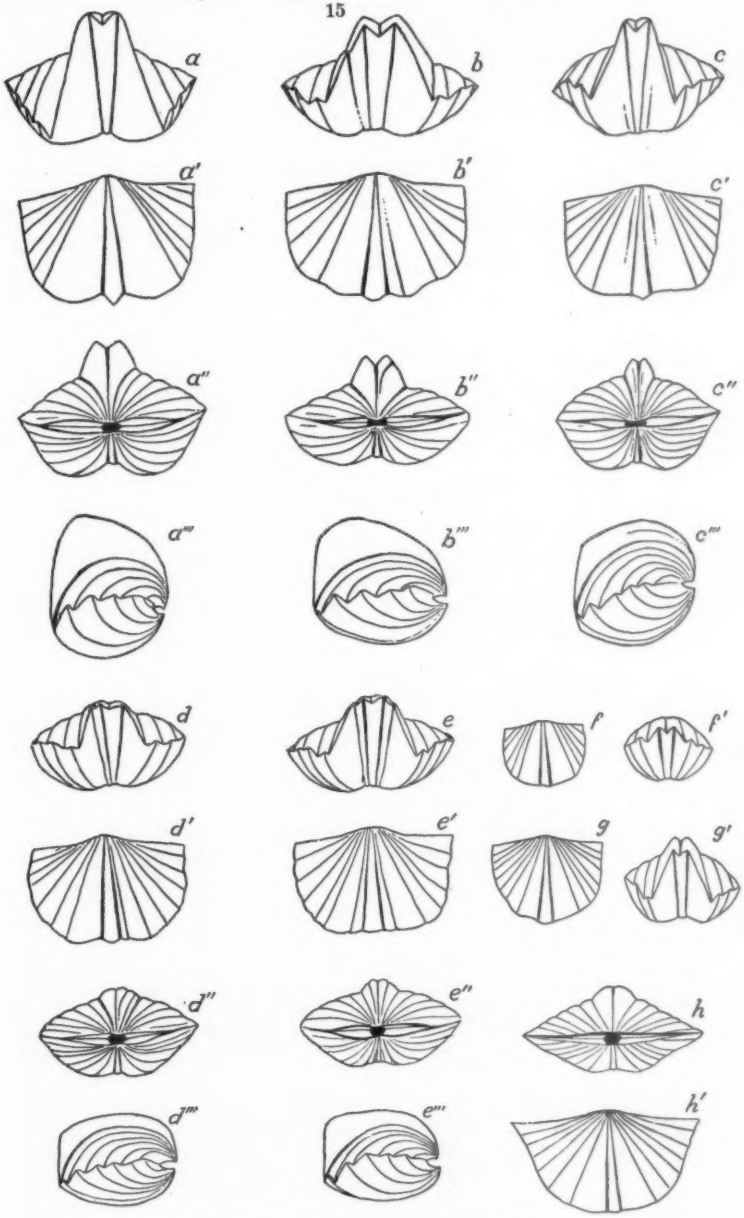

(See bottom of page 28 for description.)

der of the Ordovician of this country was, as we shall see, taken up and passed on by the *laticosta* and *costata* types.

The fact that a more nearly normal form of *lynx* survived to the close of the Ordovician (Madison beds) has already been pointed out. This form seems to represent the final expression of the type—a shell, primitive in many respects, though of large size; and undergoing a last attempt to accommodate itself to changing conditions.

*Platystrophia laticosta.**—This is one of the most interesting and one of the least understood types of *Platystrophia.* It seems to be confined to American faunas, and occurs here only in the Cincinnati group of the Ohio valley, where it ranges through the Lorraine and reappears at the base of the Richmond formation.

Meek† has admirably described this variety and little can be

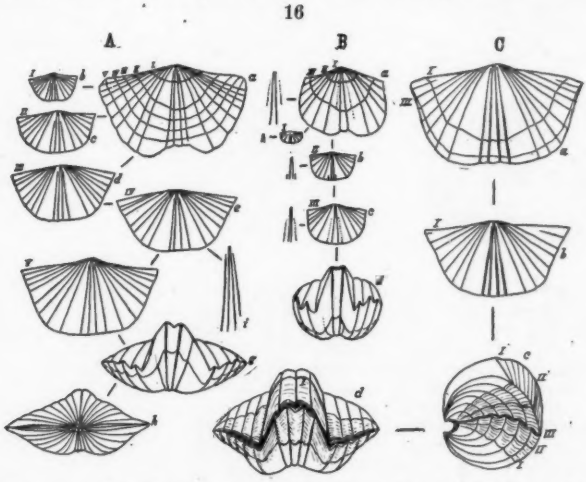

FIG. 16. *A* and *C*, *Platystrophia laticosta* from Vevay, Indiana; × ⅔. *B*, *P. costata* from Cincinnati, Ohio; × ⅔. *A*, shows growth stages *I–V* separately drawn (*b-f*), and anterior (*g*) and posterior (*h*) views: note the disappearance of the right hand plication of the sinus after stage *V*. *B*, shows the initiation of a second and third plication in the sinus at stage *II* (*a*, *b*) and their disappearance at stage *III* (*a*, *c*). *C*, is a gerontic individual of *P. laticosta;* note the increase of the cardinal angle after stage *I*, and the reduction in the height of the fold, and strong growth varices (*c*, *d*). *A* and *C*, author's collection; *B*, Yale collection.

added in regard to its adult characters. Its minute study, based upon hundreds of individuals, has, however, developed unsuspected relationships, which I shall now point out. Fig. 15 gives

* James, Cat. L. Sil. Foss. Cincinnati Group, 1871, p. 10.

† Pal. Ohio, i, 1873, p. 116, pl. 10, fig. 4. *P. chama* deVerneuil (not *P. costata* Pander) may be related to *P. laticosta.*

some idea of the variation of *laticosta*; *e* is a normal individual with one large (median) and two small (lateral) plications in the sinus. *a* has but one plication in the sinus and the fold is extremely elevated. *b* to *d* are intermediate between these two. In seeking the derivation of this type as in other types of *Platystrophia* the growth stages are of paramount importance. In fig. 15, *c*, are shown two lateral plications in the sinus originating at the usual distance from the beak but disappearing a little over half way from the beak to the front margin. Fig. 16, *A*, shows the inception of this process of reduction of the lateral plications of the sinus. Here only one plication is affected, and that only near the front margin. Fig. 16, *B*, shows the same tendency in *P. costata*.

Considering now the growth varices (fig. 16) it is evident that *laticosta* becomes progressively more transverse during ephebic stages, while *costata* becomes progressively less transverse; the early stages of the two being identical and also identical with the early stages of *P. lynx*. In *P. laticosta* the cardinal angle is progressively 72°, 73°, 63°, 68°, and 70°, returning thus in gerontic stages to near the angle of an early ephebic stage. In *costata* (fig. 16. *B*) the angle changes from 95° to 78° to 82° to 99° in the fully adult stage, while in gerontic stages it may be as much as 113°. The largest angle seen in any stage of *laticosta* was 95°. Both *laticosta* and *costata* are therefore derived from a primitive *lynx* by a reduction of the number of plications, and an elevation of the fold. The relation of *laticosta* to *costata* is not a linear one; but after the establishment of a pauciplicate stock like the young of both (see ante), a divergence occurred, one branch taking the direction of an elongate narrow type (*costata*) and the other the direction of a transverse acuminate type with extremely high fold (*laticosta*).

The above mentioned uniplicate *laticosta* (fig. 15, *a*) is found in the Upper Lorraine and is not to be confused with *P. costata*. The former has an exceptionally high fold but the same contour as a normal *laticosta*, from which variety it is derived, and with which it is connected by every possible gradation. If it is desired to distinguish this form from *P. laticosta*, it may conveniently receive the name of *unicostata*.*

In the *Dalmanella Meeki* zone which intervenes between the Lorraine and Richmond beds, no specimens of *Platystrophia* occur, except at the very top of the zone where the typical

* The *dentata* and *crassa* of American authors undoubtedly include these two forms *costata* and *unicostata*. The former term will be shown to apply only to certain foreign and Upper Silurian biplicate types. Since the term *crassa* confuses two distinct forms it had better be abandoned altogether, especially since the form to which it was intended to apply is the *costata* of Pander.

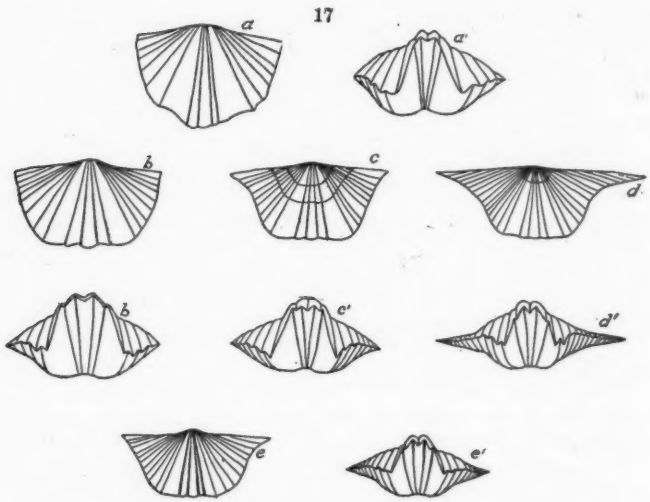

FIG. 17. Group of *Platystrophia acutilirata* from the base of the *acutilirata* zone (Lower Richmond) Tanner's creek, Indiana, with forms transitional to *P. laticosta* from the same zone. *aa'*, *P. laticosta*, after Meek; *bb'*, *P. laticosta*, Tanner's creek, lower Richmond; *cc'*, intermediate *acutilirata* type; *dd'*, very mucronate *acutilirata*; *ee'*, normal *acutilirata*. Author's collection.

laticosta again makes its appearance. Within the next 20 ft. of strata this *laticosta* is modified into a typical *acutilirata*. Fig. 17 will make this clear. *The transition has been noted in so many individuals, from so many different localities, that there can be no doubt as to the correctness of this view of the relationship of these two forms.* If any additional evidence were needed, it is furnished by a study of the early stages of *acutilirata* and by the general angularity and high fold of the latter species; as well as by the absence of the *laticosta* type from the *Rhynchotrema* zone, where *acutilirata* abounds.

Few individuals of *laticosta* present pronounced gerontic modifications. Such changes when they do occur produce a shell of extreme gibbosity, and with a large cardinal angle (from 65° to 74° in one specimen), so that the contour of the shell approaches that of *P. lynx*. Fig. 16, *C*, illustrates this. Normal growth ceased at stage *I*: the fold subsequently becomes lower relative to the size of the shell (cf. stages *I* and *II*), and the frontal profile becomes regularly curved instead of being truncated as in ephebic stages (cf. fig. 16, *Cc*, with fig. 15, *e'''*); so that the profile also resembles that of a gerontic

P. lynx. In fact the gerontic *laticosta*, in almost every feature in which it departs from the normal adult type of the variety, approaches *P. lynx*.

In another place* I have pointed out the intimate connection between *Platystrophia laticosta* and *P. lynx*. The examination of many thousands of specimens of these forms has failed to bring to light any character which does not show transitional stages from one to the other. The relatively greater strength and smaller number of the plications of *laticosta* is its most constant character, and with this is usually combined auriculation and prolongation of the cardinal extremities: the latter character is, however, by no means uncommon in *P. lynx*. It seems best therefore, to the writer, to consider *laticosta* as a variety of *lynx*, transitional between it and the species *acutilirata*.

For comparison with the uniplicate *laticosta* I have inserted (fig. 15, *h*) figures of *P. chama* traced from deVerneuil's figures.† That author says (op. cit.) he succeeded in obtaining a complete series of transitional forms between the small narrow type of *chama* (= *costata* Pander) and the acuminate type figured. As I have not seen any specimens of *P. chama*, deVerneuil's statement must be taken as indicating the relation of these two forms; though I strongly suspect that *chama* may bear no closer relation to *costata* Pander than does the uniplicate *laticosta*. The latter may, indeed, be the form to which it more nearly corresponds.

Platystrophia acutilirata.‡—Another type, found only in American faunas, is *Platystrophia acutilirata* Conrad, which is confined to the Richmond beds of the Cincinnati group.§ This species presents the most remarkable similarity to a *Spirifer* of any of the types of *Platystrophia*. The breadth may become as much as three times the length; and the cardinal extremities are frequently as acuminate as those of an average *Spirifer mucronatus*,‖ yet between these extreme forms

* This Journal, July, 1902, p. 14.

† Géol. de la Russie, 1845, pl. v. figs. 1*b*, 1*c*.

‡ Conrad, Jour. Acad. Nat. Sci., Philadelphia, viii, 1842, p. 260.

§ Keyes lists this form from the Hudson shales (Cincinnati) of Louisiana, Missouri. As he gives no figure or description, it is uncertain whether his specimens are really referable to *acutilirata* or belong to the acuminate type of *lynx*. See Keyes, Geol. Missouri, vol. v, Paleontology, 1894, p. 66.

‖ Prof. H. S. Williams has called my attention to the fact that Atwater's specimen of *S. pennatus* came from a locality in Ohio to which examples of *Platystrophia acutilirata* might have been transported by streams. While I do not believe that *Spirifer pennatus* is a *Platystrophia acutilirata*, the possibility of this being the case together with the total inadequacy of Atwater's description and figures, would seem to warrant abandoning his name altogether and returning to the well known name of *mucronatus* for this species of *Spirifer*. See Atwater, this Journal, ii, 1820, p. 244, pl. I, figs. 2, 3.

and a normal *P. laticosta* there is, as above stated, *every possible gradation*, as there is between the latter and *P. lynx.**

P. acutilirata presents considerable variation, chiefly, however, in becoming first progressively more and more acuminate, and second in becoming, in the upper part of its range, retrogressively less and less acuminate. The shell index varies in progressive series from less than 1·6 to more than 2·7 and in retrogressive series from the latter figure to 1·4. The number of plications varies from 18 or 19 to 37 or 38, of which three are almost invariably in the sinus (four on the fold).† The cardinal angle varies in progressive series from 80° to 40° and in retrogressive series from 40° to 90°, which is very nearly the normal angle for *P. lynx*. These changes may frequently be noted in a single individual. Fig. 18, *e*, shows a retrogressive individual from the upper Richmond beds of Richmond, Indiana.‡ This specimen is inequilateral through inequality of growth and not as a result of deformation after fossilization. Such lack of symmetry is frequently met with among these retrogressive individuals. The early ephebic stage (*I*) is almost identical with such a form as fig. 17, *b*. The normal *acutilirata* stage is shown at *II* (fig. 18, *d*, illustrates the same thing). The cardinal angle here changes from 76° in stage *I*, to 50° in stage *II*, back to 77° in the final stage (using the right-hand angle in each case). Fig. 18, *f* to *k* with the degrees marked to the right, indicate the changes for other individuals. Fig. 18, *k*, represents a specimen from the lower part of the range of *acutilirata*.§ Here all the stages are progressive,

* Prof. D. W. Dennis has called attention to the change from narrow to greatly extended forms of *P. acutilirata* in traversing the Richmond section from the foot to the head of the gorge of the Whitewater river. He did not, however, recognize the relation of *acutilirata* to *laticosta*. Dr. Dennis also calls attention to the variation of *Hebertella* in the same section. I have already mentioned the presence of *H. sinuata* in the upper part of the Richmond section. This species is also found at the base of the Richmond beds and is there modified into the variety *occidentalis*. The latter is not however modified back into a *sinuata* but this form comes in suddenly at the top of the section. See Proc. Ind. Acad. Sci., 1898, pp. 288, 289.

† Meek says the breadth is "sometimes twice, or even, in extreme cases, three times the length of the valves;" and that there are "on each side of the mesial fold and sinus from 11 to 18 [plications], making the entire number about 26 to 40 on each valve." I see no reason to doubt his extreme figures. See Meek, Pal. Ohio, vol. i, 1873, p. 119.

‡ The retrogressive forms of *acutilirata* figured in this paper are nearly all from the falls of the west fork of the Whitewater river, one mile N.W. of Richmond. These beds come stratigraphically immediately below those of Elk Horn creek, mentioned above as containing a peculiar type of *P. lynx*. The latter beds are not exposed on the west fork. Fig. 11, *c*, is from equivalent strata just south of Weisburg Station, Ind.

§ This specimen is from Tanners creek, Dearborn Co., Indiana, one mile S.E. of Weisburg. It is associated with *Prasopora hospitalis*, *Batostoma varians*, *Leptæna rhomboidalis*, *Strophomena planumbona*, *Rafinesquina alternata*, a very convex form, and a very large form, *Hebertella sinuata*, *Streptelasma corniculum*, etc., etc.

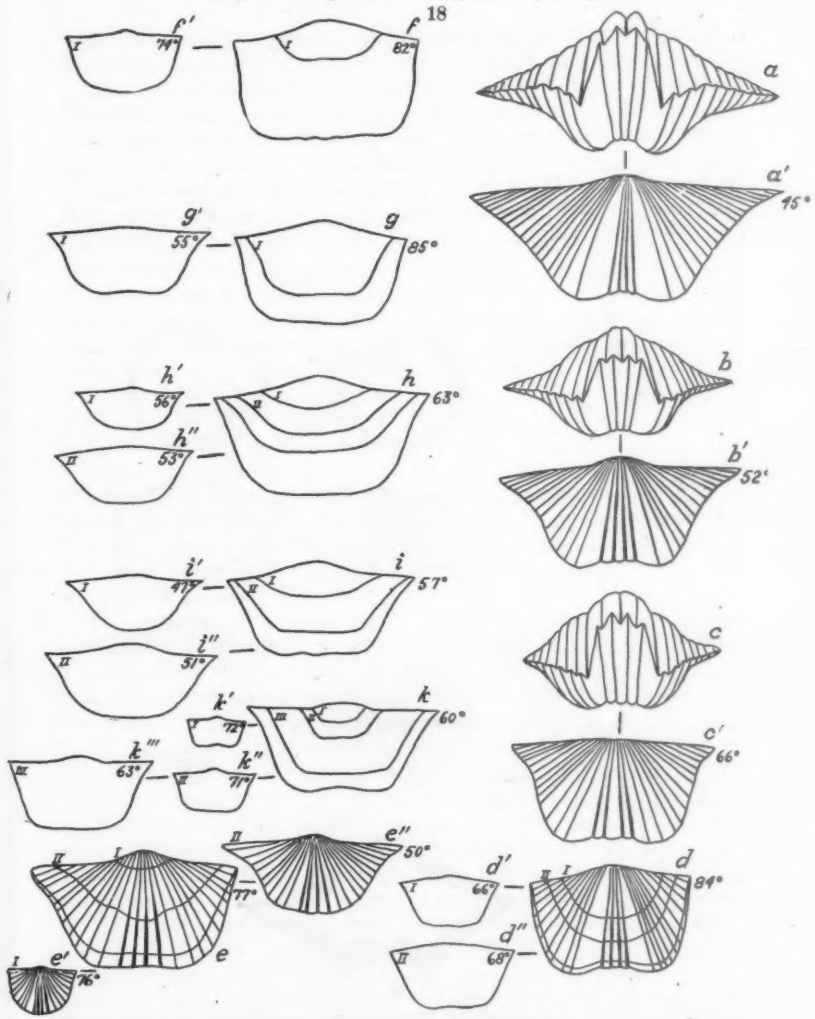

FIG. 18. *Platystrophia acutilirata* from Richmond, Indiana. *a-a'*, anterior and ventral views of a very mucronate individual; *b b'*, an intermediate form; *c-c'*, narrower, very gibbous form; *d-d''*, retrogressive type with stages *I* and *II* drawn separately to the left; *e-e''*, a similar individual showing asymmetrical growth and great increase of the cardinal angle in late growth stages; *f*, *g*, *h*, *i*, outlines of other retrogressive individuals showing increase of the cardinal angle in late growth stages; *k–k'''* an individual from the base of the *acutilirata* zone showing progressive decrease in the cardinal angle. Specimens *a–i* are from the upper part of the *acutilirata* zone. Author's collection.

i. e. the individual becomes more and more acuminate throughout its ontogeny. What is true of this individual is true of practically every individual from the same horizon.

Platystrophia acutilirata presents the most profound gerontic modifications of any member of the genus; and gives rise in even greater degree than *P. lynx* to what may almost be termed a phylogerontic group of shells representing the paracme of the *laticosta* line, of which as we have seen *acutilirata* is but an extreme manifestation. Though *P.*

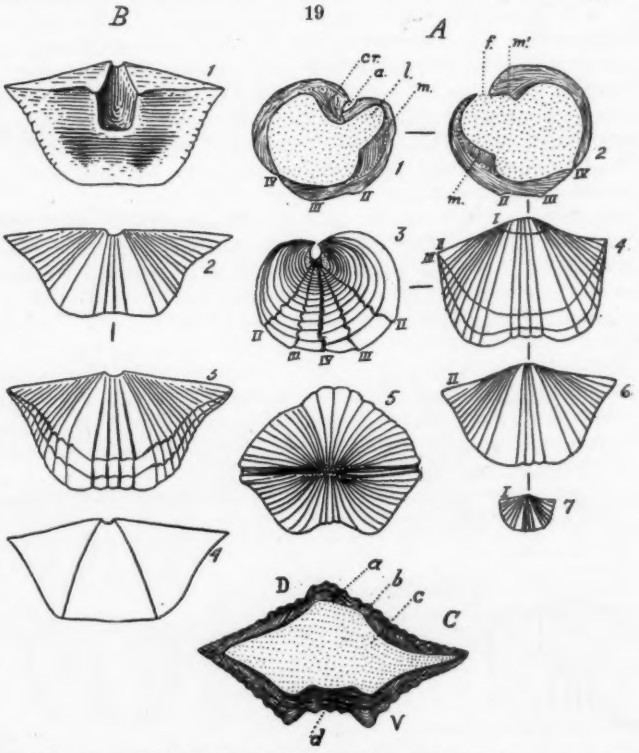

FIG. 19. Senile individuals of *Platystrophia acutilirata* from the upper Richmond of Richmond, Indiana. *A*, an extremely gibbous and greatly thickened shell; 1 and 2, median sections showing thickening and reduction of body cavity; 3, 4, 5, profile, ventral, and posterior views showing pronounced varices *II, III, IV*; 6 and 7, stages *II* and *I* separately drawn. *B*, another individual; 1, interior showing profound muscular pit; 2, stage represented by first growth varix; 3, ventral valve showing strong varices; 4, stage represented by second varix. *C*, another individual cut transversely in the dorso-ventral plane to show thickening of shell. *cr.*, crura; *a.*, area; *mm'.*, ventral and dorsal muscular platforms; *f*, pedicle foramen; *a*, normal and *b*, senile thickening of shell; *d*, ventral muscular platform. Author's collection.

acutilirata is a much smaller shell than *P. lynx* of the Lorraine, yet the thickening of the shell in gerontic stages is greater both relatively and absolutely. The acuminate cardinal extremities are so thickened that this region of the shell becomes practically filled up with shelly deposit. The thickening of the central and anterior region of the shell is very great (fig. 19, *A*, 1 and 2), so that the actual room left for the lodgment of the soft organs of the animal is less than in unthickened shells of a much lower index, and less both relatively and absolutely in gerontic stages than in ephebic stages of the same individual. Fig. 19, *C*, of a vertical section from cardinal angle to cardinal angle of a markedly senile individual, will make this plain. The convexity (vertical diameter) of the shell is also considerably greater than in any other type of *Platystrophia*, the height being in extreme cases 1·5 greater than the length, while in *P. lynx* the extreme is 1·04 or height and length nearly equal, and in *laticosta* 1·14. The changes in contour due to senescence are profound, as has already been pointed out. Fig. 19, *A*, represents a shell in which normal growth was attained at the varix numbered *II*. The cardinal angle at this stage is 58°. In the latest stage it is 79°, and in the early stage represented at *I*, it is 76°. Here is a total change of 39°.

The retrogressive series mentioned above is produced by the acceleration of gerontic stages, till in such individuals as fig. 11, *C*, from the extreme upper Richmond beds at Weisburg, Indiana, the acuminate or normal *acutilirata* stages come on near the beaks and the adult has the outlines of a normal *lynx*. In fact, the resemblance between this shell and the true *lynx* of the same horizon is so striking, that only by a study of the stages indicated by the growth varices can they be distinguished.

Whether any Silurian Orthid was derived from *Platystrophia acutilirata* is impossible at present to determine. Certainly none of the Silurian forms of *Platystrophia* bear any close relation to this type, since they are as persistently biplicate as the latter is persistently triplicate. To be sure, many individuals from the upper Richmond beds have one or other of the secondary plications of the fold and sinus originating very near the apex, as we should expect from the marked acceleration of these shells in nearly every particular; but I have never seen a specimen in which the lateral plications manifested any tendency to disappear, nor in which there is even a suggestion of a biplicate type. The form seems to have perished very soon after its assumption of retrogressive characters. Indeed, the coming in of a strongly molluscan fauna in these late Ordovician beds seems to indicate some radical change in con-

ditions and this may account for the sudden decline and extinction of *acutilirata.*

As to the taxonomic value of the term *acutilirata* the writer is of the opinion that the form should certainly be considered as a species, although, as pointed out, it is perfectly connected by intermediate forms with *P. laticosta.* It is not, however, except in a very limited zone associated with the latter variety; and it represents such a remarkable distinctness and completeness of history after its initiation, that no one need confuse it with any other member of the genus.*

Platystrophia costata.†—It will not be necessary to enter here into the question of the synonomy of this type. DeVerneuil's objection to Pander's name was based upon the preoccupation of the term *costata* by *Spirifer costatus* Sowerby. Since the latter is a true *Spirifer* we must return to Pander's name for the present form.

Platystrophia costata (=*P. dentata* Meek; *P. crassa* James) makes its appearance in American faunas in the lower Lorraine of the Ohio Valley; and is the well known variety with a rather small, gibbous shell having one plication in the sinus and five or six on the lateral slopes. The derivation of this type has been discussed at sufficient length under the head of neanic stages of *Platystrophia.* It comes from a normal triplicate type by the dropping out of both secondary plications of the fold and sinus.

Under *P. laticosta*, mention was made of a uniplicate form of that variety. Doubtless the latter has usually been confused

*It may seem to be doing violence to taxology to distinguish a form at one stage of its history as a *variety* and at another stage as a *species under a distinct name;* nevertheless, I believe we must be prepared to take this step, since we must certainly find as the investigation of fossils becomes more minute and precise that cases such as this of *Platystrophia laticosta* and *P. acutilirata* are by no means exceptional. In this connection I may quote a passage from a timely article by Mr. O. F. Cook on categories of species (Am. Nat., vol. xxxiii, 1899, p. 292). He is comparing existing species to islands and bodies of land more or less separated from each other in "the sea of non-existence." He says, speaking of incipient species, "Although the designation by name of the various prominences or arms of a diversified island [which is gradually sinking] is desirable, even before the expected separation occurs, the prophetic tendency should, in the interest of historical accuracy, be curbed to the extent of distinguishing in category between groups which are already segregated in nature and those which are not, ... by treating them as already distinct we ignore the existence of intermediate forms and proceed as though degree of apparent difference were an index of segregation or a taxonomic substitute for it." He suggests the use of the term *subspecies* for all such non-segregated groups or *incipient species.* In this sense *P. laticosta* would be a subspecies of *P. lynx;* and *P. acutilirata* the completely segregated group or species. I have retained the more usual designation of variety for the former.

† Pander, Beiträge zur Geognosie des russischen Reiches, 1830 p. 96, pl. 11, fig. 3.—De Verneuil, Géol. de la Russie, 1845, p. 140.—Sowerby, Trans. Geol. Soc. Lond., 2d ser., vol. v, pl. 55, figs. 5–7.

with *P. costata*. The two are, however, easily distinguished and, besides, have a different range.* *P. costata* is, moreover, derived from *P. lynx* and not from *P. laticosta*, as is the case with the other form.

Platystrophia costata presents well characterized gerontic stages (fig. 16, B). These are marked by extreme gibbosity and great breadth anterior to the hinge-line so that the cardinal angle may be as great as 113°. Where the secondary plications of the sinus and fold are faintly marked in ephebic stages, they are almost sure to become obsolete in gerontic stages. The thickening of the shell does not become pronounced as in *lynx* and *acutilirata*.

The *costata* and *laticosta* types seem to have been produced simultaneously from the same pauciplicate *lynx* stock. The former did not survive the Middle Ordovician either in this country or in Europe;† but from it sprang the only genus, so far as at present known, that can be traced to the *Platystrophia* group as a radical stock. From a study of the young of *Bilobites*, Beecher‡ concluded that it was probably derived from the *Platystrophia* group. This conclusion has since been called in question by Wysogorski,§ who maintains that the punctate character of *Bilobites* removes it from the "*Orthis* group," in which he places *Platystrophia*, and relates it to the "*Dalmanella* group." It is well known, however, that punctate and impunctate shells occur in a variety of diverse groups of Brachiopods, and that the early members of a group may be impunctate, while the later members are punctate.‖

The resemblance of the early nepionic stages of *Bilobites* to the nepionic stages of *Platystrophia* has already been pointed out. The similarity between a late nepionic stage of *Bilobites* and the adult *Platystrophia costata* amounts

* *Platystrophia cypha* James is doubtless this form of *P. laticosta*. He mentions the extremely high fold and one strong plication of the sinus. The writer has never seen as many plications as he records (22 to 26), but doubtless in the upper part of its range (his specimens are from Warren Co., Ohio), the form developed a larger number of plications. See James, Cin. Quar. Jour. Sci., i, 1874, p. 20.

† See Wysogorski, Entwicklungsgeschichte, p. 15.

‡ This Jour., vol. xlii, July, 1891, p. 54.

§ Entwicklungsgeschichte, p. 9, footnote 1.

‖ The early Spirifers are impunctate; but in the Ostiolati *S. plenus* is punctate. Among the derived genera several are punctate, viz., *Syringothyris*, *Cyrtina*, *Spiriferina*. Among the *Rhynchonellidæ* all the earlier forms are impunctate, but *Rhynchopora* of the Carboniferous is punctate, though in all other respects it agrees with the earlier Rhynchonellids. Among the *Athyridæ*, *Hindella*, *Cœlospira*, etc., of the Silurian are impunctate, while *Eumetria*, *Hustedia*, etc. of the Carboniferous, are strongly punctate; *Rhynchospira* is sparsely punctate. The *Atrypidæ* are impunctate. Among the Terebratulacea, nearly all are conspicuously punctate, but in the early genera, *Rensselæria* and *Amphigenia*, the punctation is incomplete. See Hall & Clarke, Pal. N. Y., viii, pt. 2, 1893.

In *Hebertella* the early species are impunctate or superficially punctate: *the upper Richmond form is more clearly punctate.*

FIG. 20.—*a*, Young stage of *Bilobites varicus*, drawn from the beak of an adult individual, x 4: *b*, small specimen of *Platystrophia costata*, natural size; *c*, adult *Bilobites varicus*, natural size.

almost to identity in everything except size. Fig. 20, *a*, is drawn from the ventral beak of an adult *Bilobites varicus* from the Lower Helderberg of New York; and fig. 20, *b*, is a small individual of *P. costata*, from Cincinnati, Ohio. An examination of several hundred individuals of *B. varicus* has shown that there is invariably present, in well preserved material, a median plication at the apex of the ventral sinus* (fig. 20, *a*). This plication very soon becomes obsolete, so that the greater portion of the sinus is without plication of any kind. Clearly such a vestigial character is not without significance. The median plication of the sinus of uniplicate and triplicate types of *Platystrophia* is a character that is never absent whatever other modifications may affect the shell; the presence of this persistent character in a derived genus is to be expected, and affords, together with the evidence from development, a virtual demonstration of the derivation of *Bilobites* from *Platystrophia*. Moreover, since the *costata* and *unicostata* types of the latter genus present the most profound modifications of fold and sinus, and since this extreme elevation of the fold must have been related to a marked separation of the brachia and the latter character have been responsible for the production of a bilobate shell, we are justified in considering either *costata* or *unicostata* as the ancestor of *Bilobites*. *P. costata* is preferred because of its wide distribution and greater abundance. It would be interesting to know in what province the early stages in the evolution of *Bilobites* were passed. No trace of the genus has so far been found in the late *Ordovician*. It is extremely rare in the late Clinton and Niagara of this country; but occurs somewhat abundantly in the equivalent formations of the Island of Gotland. Since *P. costata* is abundant in the European province, we may look there rather than in America for the transitional forms to *Bilobites*.†

The taxonomic value of the term *costata* need not detain us long. De Verneuil regards *P. chama* as a variety of *P. bifora* (?), and in this country the form is also usually placed as a variety. It has been shown that there are in the Cincinnati group abundance of transitional forms between *costata* and the

* This characterizes all the other species of *Bilobites* as well.

† Mr. C. J. Sarle of Rochester, N. Y., has found a form of *Bilobites*, similar to *B. verneuiliana*, in the Clinton of Rochester, N. Y., where, in one layer, it occurs rather abundantly.

pauciplicate *lynx*. For the European form I can not speak. It may even prove to be distinct from ours, though it certainly seems to be identical. The wide distribution of *costata* would seem to entitle it to rank as a species, yet the evidence at present available is rather in favor of regarding it as a variety of *P. lynx*, the differentiation of which began quite early in the history of the genus.

Platystrophia biforata.—The reasons for considering this species as distinct from American Ordovician forms of *Platystrophia* have already been stated, and the main features of the type described. Little can be added in regard to the foreign forms. The Russian *biforata* occurs in beds as low as the Trenton, and in this country, a shell of quite similar aspect, and of unquestioned biplicate type, is found in the Trenton of the Lake Champlain region* associated with the normal *lynx* type.† This association is of great interest since it shows that the differentiation of these two species was going on in the early Ordovician, and also that there was free intercommunication between the American and European Province at that time.‡ The total absence of *biforata* from American deposits throughout the remainder of the Ordovician might also indicate a closure of this avenue of communication early in that period.§

In the Clinton of this country we again meet with a biplicate *Platystrophia* strikingly similar to the Russian *P. biforata*. The writer has examined about 50 individuals from Rochester and Gasport, N. Y., Dayton, Ohio, Irvine, Kentucky, and Richmond, Indiana. These present considerable variation, mainly in the number of plications, which may be all the way from 16 or 18 to 46 on the valve, a greater range than in any other type (see fig. 21).

* Mr. P. E. Raymond sent me specimens from the Crown Point section. The species occurs there in the upper part of the section. All the specimens sent may be of the biplicate type, although several have three plications in the sinus. The exfoliation at the beaks renders it impossible to make sure to which type the latter belong. Billings figures a Canadian *Platystrophia* with rounded cardinal angles and four plications in the sinus, two of which appear to arise at the apex. This specimen is very similar to several of the Crown Point forms, and may very likely belong to the same type. See Raymond, Bull. Am. Pal., No. 14, 1902, pp. 27, 28; and Billings, Geol. Canada, 1863, p. 167, fig. 149 *a*.

† Some specimens collected at Ft. Cassin, Vt., by Mr. H. M. Seeley, are clearly referable to *P. lynx*.

‡ See Frech, Lethæa geognostica, Theil I. Lethæa Paleozoica, 1897, 2, p. 100. Ruedemann, Bull. N. Y. St. Mus., No 42, vol. 8, 1891, pp. 561-564; Ibid., No. 49, 1901, pp. 104-107 and footnote p. 107. Ulrich and Schuchert, Bull. N. Y. St. Mus., No. 52, 1902, pp. 633-663.

§ Cf. Dana, Man. Geol. 4th ed., 1894, p. 536.—Ruedemann, Am. Geol., June, 1897, pp. 367-391.

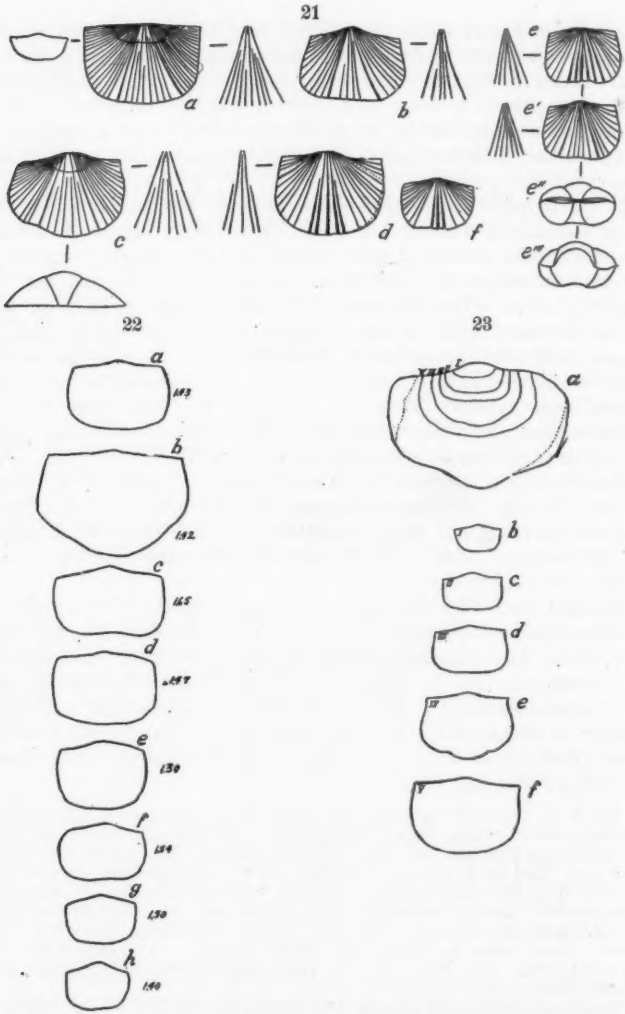

FIG. 21. *a, b, c, d, f, Platystrophia biforata* from the Clinton of Rochester, N. Y.; *a, b, c,* dorsal and *d, f,* ventral valves: adjacent diagrams show method of origin of plications of fold and sinus. *e, P. biforata* from Wesenberg, Russia (Ordovician); *e,* ventral; *e'*, dorsal; *e''*, posterior; *e'''*, anterior views. *a, b, c, d, f,* collection of Mr. C. J. Sarle, Rochester, N. Y.; *e,* Yale Collection.

FIG. 22. Series of Clinton *Platystrophia biforata* showing variation in outline and index. Value of index given to right of each shell. Collection of Mr. C. J. Sarle, Rochester, N. Y.

FIG. 23. Specimen of *Platystrophia biforata* from the Clinton of Gasport, N. Y., showing growth varices *I-V* and the stages separately drawn (*b-f*). Collection U. S. National Museum.

The number of plications in the sinus varies from two to nine (three to ten on the fold), which is also a greater range than observed in any other type. All except the primary plications originate at a considerable distance from the beak. The amount of variation in the shell index and contour (fig. 22) is less than in the *lynx* type, and the sinus is never profound. The average index is about 1·4, or very near that of the Trenton *lynx*. The cardinal angle is difficult to determine with accuracy owing to the worn condition of most of the specimens; but is scarcely ever less than 90° and may be considerably over 100°. The dorsal valve is usually considerably more convex than the ventral, especially in the umbonal region, but the incurvature of the beaks is not as great as in *lynx*. Internally *biforata* has the dental sockets more deeply excavated and the crura more prominent. The muscular scars have not been observed.

The British types of *Platystrophia* have given the writer considerable trouble because of the general absence of specimens of that province from American collections. The figures and descriptions given by Davidson and others throw very little light upon the subject. All their Wenlock examples certainly belong to the *dentata* type, as is pointed out later, but the position of the *Ordovician* forms cannot be determined. The var. *fissicostata* McCoy,* judging from the figures given by Davidson†, strongly resembles our Clinton forms. It has, according to McCoy, "four ribs on the rostral part of the mesial furrow, the two outer of which usually branch at four or five lines from the beak, the others branch irregularly lower down once or twice; lateral ribs varying from six to fifteen within three or four lines from the beak, branching irregularly, some into two, others into four, with age; surface crossed towards the margin with sharp striæ of growth. This variety does not seem to have been noticed either in Russia or America, yet it is extremely common in our old rocks . . . ." This variety, according to Davidson, "abounds in the Caradoc" at numerous localities and in the Coniston, etc. Now, the only American type known to the writer that ever has bifurcating plications is the *biforata* of the Clinton, in which group this peculiarity is common.‡ Again, the presence of "four ribs on the rostral part of the mesial furrow" is a character absolutely unknown in the *lynx* type, but common in the *biforata* type. On the whole, it seems likely that *fissicostata* is a true *biforata* similar to

* British Pal. Foss., 1852, pp. 192, 193.

† Silurian Brachiopoda, 1871, pl. xxxviii, figs. 15-17, 19.

‡ Mr. Foerste has already called attention to this fact. Bull. Dennison University, I, 1885, p. 80.

our Clinton forms.* The derivation of *P. biforata* has been discussed at some length in connection with *P. lynx*. It is plain that we must look to European deposits for the fullest light on this point. I am convinced that whatever new evidence arises will be found to support the position taken here, that *P. lynx* is really the more primitive. The history of the species after its reappearance in our Clinton faunas is not as fully understood as could be wished, owning to the small amount of careful stratigraphic work that has been done on this series of rocks. Too much emphasis can not be laid on the necessity of *accurate, detailed, and comprehensive* work of this sort. Nevertheless the main features outlined above are not likely to be modified by future investigations.

To *Platystrophia biforata* is here assigned the rank of a species occupying the same position of prominence in relation to the European and Silurian faunas that *P. lynx* does in relation to the American Ordovician faunas. So far as is now known, the type did not survive the Clinton.†

Platystrophia dentata.‡—So much confusion exists in this country in regard to this type of *Platystrophia* that it will be necessary to enter somewhat in detail into the question of synonomy.

In 1830 Pander described and figured *Porambonites dentata, P. costata, P. brevis*, and *P. recta*. The affinities of the last two are uncertain, but the first two represent very characteristic and widely distributed types of *Platystrophia*. *P. dentata*, according to both the figures and description given by Pander, has two plications in the sinus (three on the fold) and about five on each side. The sinus is deep, the contour of the shell rounded, and the profile plump, or even gibbous. This form was refigured and described by deVerneuil,§ who says that it passes by insensible gradations into *biforata* on the one hand and *chama* (=*costata*) on the other. Davidson‖ placed *dentata* in the synonomy of *biforata*. In 1873 Meek¶ described under this name a form which he says is "referred in Mr. James's list to *O.* [*Orthis*] *dentata* of Pander." In regard to this, Mr. James** says, the specimens "were wrongly put up

* According to Schmidt, *fissicostata* occurs in Russia at Muddis, Koil, Lyckholm, and Hohenholm, in the Lyckholm beds, which are equivalent in age to the upper part of our Cincinnati group. See Schmidt, Archiv. für die Naturkunde Liv.-, Ehst.- und Kurlands, 1ter ser, 2ter Band, 1te lieferung, 1858, p. 213.

† *Delthyris brachynota* Hall (Geol. 4th Dist. N. Y., 1843, p. 71) is a *P. biforata* of the Clinton type.

‡ Pander, Beiträge zur Geognosie des russischen Reiches, 1830, p. 96, pl. 11, figs. 4 a–e.

§ Géol. de la Russie, 1845, p. 138, pl. iii, fig. 5 a–f.

‖ Silurian Brachiopoda, 1871, p. 268.

¶ Pal. Ohio, i, 1873, p. 117.

** Cin. Quar. Jour. Sci., i, 1874, p. 21.

for Mr. Meek, Pander's *O. dentata* not being sent." It seems that Meek received the labeled specimens from James. The latter further says: "I now propose the above name [*crassa*] for the shell described by Meek [as *dentata* Pander]." Meek (loc. cit.) expresses grave doubts as to the identity of the form with Pander's species. He says: "I doubt very much, however, whether it agrees with that variety [*dentata*], which is described by McCoy, from British specimens, as having constantly two plications in the sinus." Nevertheless, Miller* subsequently referred the form to *dentata* without further remark. It is known now that Meek's *dentata* is the same as *crassa* James; and it has been pointed out that both are the same as *costata* Pander. The name *crassa* therefore lapses into the synonomy of *costata*.

Platystrophia dentata Pander is a perfectly distinct type found in the Ordovician of Russia and the Niagara of both Europe and America. To this type belong the Anticosti and Gotland forms, as well as the Niagara form of Kentucky and Indiana.

In regard to the variation of *P. dentata*, there is little to be said. Shaler's measurements of a series of twenty shells from Anticosti (which are now before me) show but little variation, and the same is true of the Gotland specimens, about thirty of which I have measured. There is also scarcely any variation in number of plications. One specimen from Gotland has three instead of two in the sinus, though only two start at the beak. The Kentucky specimens figured by Nettleroth also have at the front margin more than the usual number of plications in the fold and sinus,† but otherwise closely resemble the Gotland form.

As to the derivation of *P. dentata*, the same argument that derives the closely related *P. biforata* from a primitive uniplicate stock holds in the present case. *P. dentata* was derived from such a primitive stock, probably at about the same time with *P. biforata*, and by the same process of acceleration of the point of bifurcation of the primary plication of the sinus. The transitional stages are to be sought in Russian deposits, since *dentata* is absent from the American Ordovician.

In Niagara time the species spread westward into Gotland, and from there into England and Ireland and the Gulf of St.

* Cin. Quar. Jour. Sci., vol. ii, 1875, p. 27.

† On the Anticosti form see Shaler, Bull. Mus. Comp. Zoöl., iv, 1865, p. 67, and Brachiopoda of the Ohio Valley, p. 44. This is the form to which he gave the name *regularis*. On the Kentucky form see Nettleroth, Kentucky Fossil Shells, 1889, p. 35, pl. 29, figs. 18, 19.

Lawrence.* By another route the form reached the Mississippi area of this country, where it is very poorly represented.†

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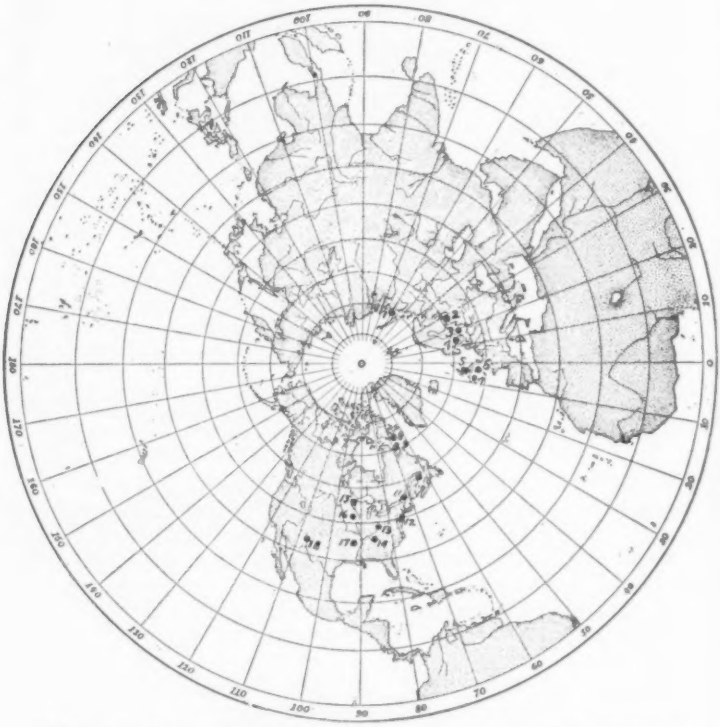

FIG. 24.—Map showing distribution of *Platystrophia*. 1, Khabarova; 2, Russian Province; 3, Island of Gotland; 4, West Gotland; 5, Scotland; 6, Wales; 7, Ireland; 8, Baffinland; 9, Akpatok Island; 10, Anticosti; 11, New York—Canadian Ordovician province; 12, New Jersey; 13, Cincinnati region; 14, Tennessee region; 15, Minnesota; 16, Missouri; 17, Arkansas; 18, New Mexico. Stereographic projection, after Penfield.

* *Platystrophia* occurs in the Wisby (Unter-Mergel) formation of Gotland (Schmidt), associated with *Bilobites biloba*, *Rhipidomella hybrida*, *Strophomena depressa*, *Rhynchotreta cuneata*, etc., and in the lower part of the Middle Gotland formation. These beds are equivalent, according to Lindström, to the Wenlock of Britain (Niagara of this country). See Schmidt, Archiv. Liv.-, Ehst.- und Kurlands, ser. i, ii, 2, 1854 pp. 426, 453, 454; and Lindström, Of. Sven. Vet. Akad., xvii, 1860, p. 381; Neues Jahrbuch f. Min. Geol. u. Pal., 1888, i, pp. 147–164.

† An occasional individual from the Clinton of Rochester, N. Y., presents somewhat the appearance of *P. dentata*, but with a larger number of plications and a shallower sinus. They are probably the young of *P. biforata*.

From the Niagara of Osgood, Indiana, I have a single specimen (Schuchert collection) which is identical with the neanic stage of the Gotland form. It may be an immature individual.

The presence of the Gotland type of *Platystrophia dentata* in the Niagara of the Ohio valley is of interest in connection with the strong resemblance of the Silurian faunas of the Chicago area to the Gotland faunas, pointed out by Weller,* and indicates a westward movement of the latter through the Hudson Bay route during Silurian time. In this connection it is also to be noted that the *Platystrophia* of the Wenlock of England and Ireland, judging from Davidson's figures,† is of the same type as that of Anticosti, that is, larger and less angular than the Gotland form. The relations of these several geological provinces will be readily understood by reference to the map, fig. 24. The extremely small size and simplicity of the Gotland and Osgood specimens is of special interest. Some of the former have in the adult but four plications on the lateral slope, and are therefore strictly comparable to the neanic stage of the normal Ordovician types. Such a complete return to the primitive type is rarely seen (see No. 16, and xix, fig. 27).

Platystrophia dentata is fully entitled to rank as a species, although in the Ordovician deposits of Russia, according to de Verneuil, it is connected by intermediate forms with *P. biforata*. Its distinctness and wide distribution during the Silurian are facts of greater import than the presence of such linking forms in the Ordovician.‡

Abnormal and Pathologic Types.—No truly pathologic shells of this genus have come to the writer's notice, with the exception of a series of specimens submitted by Mr. Charles Schuchert of the U. S. National Museum. These shells, two of which are shown in fig. 25, are from the Richmond beds of Waynesville, O. They are all small, frequently distorted, as in fig. 25, *a*; and show a pronounced tendency to obsolescence of the plications at varying stages of growth. In fig. 25, *a*, this tendency does not manifest itself till late in the ontogeny, after the formation of a very conspicuous growth varix. In fig. 25, *b*, the plications become obsolete a short distance from the apex of the beak, and farther forward regain nearly their normal strength.

* Jour. Geol., vi, 1898, p. 697. Cf. Dana, Man. Geol., 4th ed., 1894, p. 536. De Lapparent, Traité Géol., 1900, pp. 809, 823 (Maps).

† Silurian Brachiopoda, 1869, pl. xxxviii, figs. 11, 20, 24.

‡ It may be well when these early linking forms of *P. biforata* and *P. dentata* are more carefully studied to distinguish them by a varietal or subspecific name, as I have done in the case of *P. laticosta*.

It is rather difficult to assign these shells to any one of the common types of *Platystrophia.* From their occurrence and association, as well as from the aspect of the early ontogenetic stages, it seems almost certain that they are pathologic individuals of the *acutilirata* group. The individual shown in fig. 25, *a*, certainly presents every appearance of a normal *acutilirata*, up to the formation of the first strong growth varix. When normal growth was interrupted the shell reverted to a simpler, more primitive type, so that the later stages are strongly suggestive of *P. lynx.* The obsolescence of plications which, we have seen, characterizes gerontic stages only of normal shells, here affects ephebic stages as well, and to a profound degree. In both cases it is the direct result of the failing vitality of the organism. In the former case, however, the failure is a normal phase of ontogeny; in the latter, it is due to the stress of an adverse environment, to which the organisms attempted, with varying success, to adjust themselves.*

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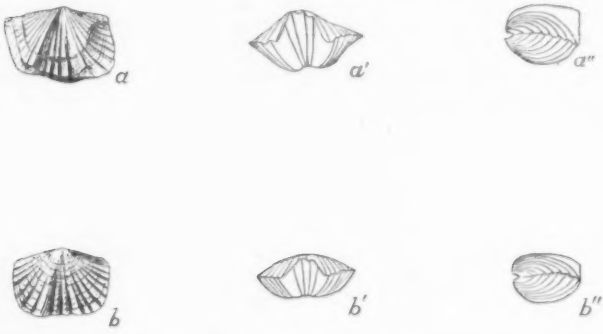

FIG. 25.—Pathologic individuals of the *acutilirata* type from Waynesville, O. In *a* the shell is greatly distorted owing to irregularity of growth, and the plications are obsolescent near the lateral margins. In *b* the plications become nearly obsolete a short distance from the beak and then continue with nearly normal strength to the margins. Schuchert collection.

* This subject has been ably discussed by Hyatt. Genesis of the Tertiary species of Planorbis at Steinheim, Anniversary Mem. Bos. Soc. Nat. Hist., 1880, p. 15.

[To be continued.]

ART. II. — *On Ruling Concave Gratings;* by WILLIAM ROLLINS.

LYMAN has shown that the Rowland concave grating gives false spectral lines so sharp and clear "there is probability and some evidence" they have been mistaken for real lines. As the concave grating is a beautifully direct method of obtaining spectra, it seemed desirable to consider the causes of its defects and try to remedy them, rather than to return to flat gratings with their lens complications.

Briefly stated, the process of preparing a concave grating is to grind and polish the surface of the metal block to the proper curvature, afterward mounting it on a carriage moving on straight ways by means of the long nut of the precision

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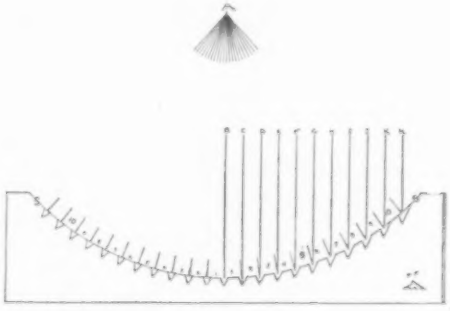

screw, which carries the metal blank under the diamond as the screw turns. This method, while well adapted to making flat gratings, does not yield concave gratings in which the grooves cut by the diamond are the same distance apart, and cannot produce them with sides having equal faces or forming the same angles with the surface of the metal in different parts of the grating. The shorter the focus of the grating the more marked are these defects.

Figure 1 is a diagram intended to show them exaggerated. The lines B to K represent equal movements of the grating under the diamond point, as produced by the uniform motion of the screw. If the grating were flat the resulting cuts would be equally spaced, while the angles formed with the surface by the sides of the cuts would be alike in all parts of the grating. In the case of the curved grating the distance between the cuts, measured on the surface of the grating, increases from the

center toward each end, as may be seen at 1 to 10 on the right of the figure, while the angles formed with the surface by the sides of the cuts vary constantly; moreover, the width of the faces of the same cut is different. The first defect might be corrected by a compensating device attached to the spacing screw nut, but the second and third cannot be with the present methods of ruling. If the block to be ruled were fixed, the diamond point pivoted at a center, A, corresponding with the center of curvature of the grating mechanism, could be arranged to move the diamond through equal arcs, producing equal

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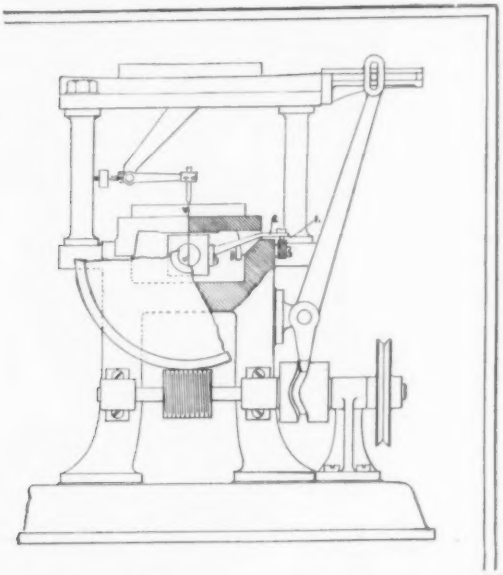

spacing and lines with equal faces and equal angles with the surface, as shown on the left of the figure at 1 to 10. In the case of seven meter gratings the arm would be so long that vibration might be difficult to deal with. Instead of moving the diamond through an arc, the carriage moved by the screw might be pivoted at the center of curvature of the grating and swing through an arc on curved ways; the nut not being rigidly attached to the carriage, but imparting motion to it by an arm. On account of the vibration factor a different method has been chosen for illustration. The usual screw is used, with a long nut to impart motion to the carriage, which moves on curved ways, instead of on flat ones, as at present in all ruling

machines. The size of the curved ways is such that the blank moves under the diamond in an arc whose radius is the same as the curvature of the grating. This causes the cuts made by the diamond to all have the same angle with the surface and their sides to be of equal widths. It does not make the spacing equal, but this may be compensated for as already mentioned. The plan of compensation shown in figure 2 was

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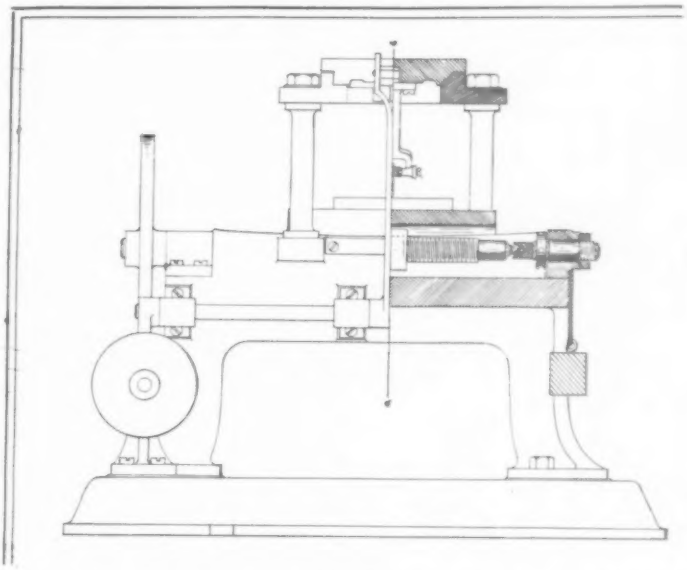

devised by Mr. William Gaertner, to whom and to Captain Khotinsky I am indebted for working out the drawings shown in figures 2, 3, 4. The nut in this machine is not rigidly attached to the carriage carrying the grating, but motion is imparted to the carriage by means of a projecting arm, which, sliding on a curved way, allows the nut to turn sufficiently to equalize the spacing.

In figure 5 another way of carrying out the principle is illustrated diagrammatically, the curvature of the grating being made very short to show the idea more clearly. The block, BK, to be ruled is mounted on the carriage, C, which moves in an arc on curved ways, motion being imparted to it from the long nut, SN, by a band of thin, tempered steel attached at N′ and N‴. As the nut SN is moved to the left, in the direction of the arrow 1, the carriage, C, turns in the direc-

tion of the arrow 2, as shown by the dotted lines, bringing different parts of the block, BK, under the ruling diamond, D. This arrangement requires no compensating device, except for the periodic errors of the screw, which may be present in any form of ruling machine. In the case of a concave spherical grating this mechanism would make the lines with equal spaces, while if a section were cut through the grating, as in figure 1, the grooves would all have the same angles with the surface. It will always be mechanically impractical to make a

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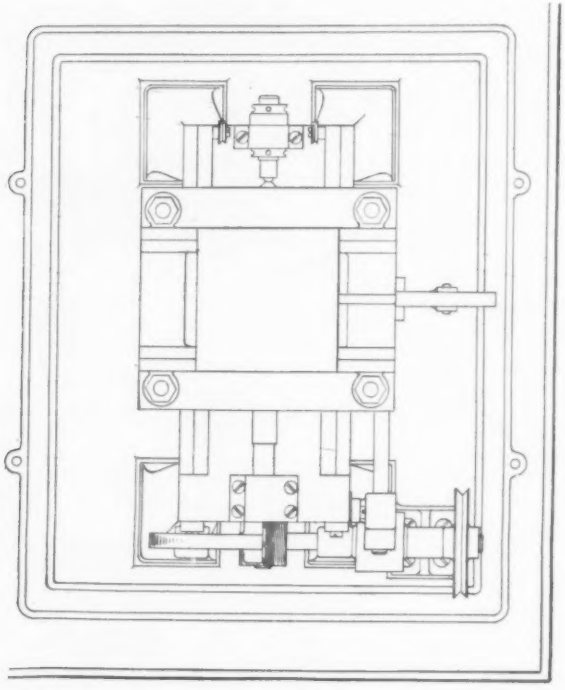

machine in which this is true through the whole ruled surface of a concave spherical grating, but if the surface of the grating is concave cylindrical then the plan shown in figure 5 is capable of overcoming all the defects mentioned in the first part of the paper. Another difficulty with the present methods of ruling concave spherical gratings remains to be considered, namely, the diamond must rule both up and down hill. No diamond does this well, consequently the forward and back

motion of the diamond should be controlled by a carriage moving on curved ways, that the long axis of the diamond may always preserve the same angle with the surface of the grating.

For the idea of applying the curved ways to the movement of

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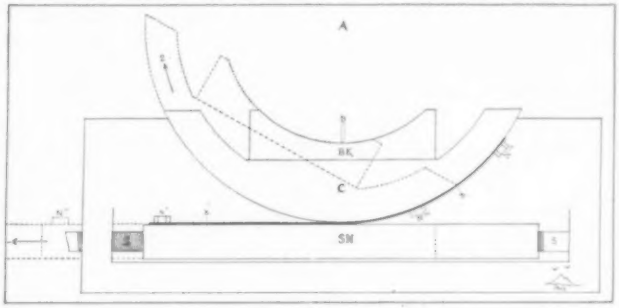

the diamond I am indebted to Captain Khotinsky, whom I engaged to make the drawings for a ruling machine which was to embody the ideas which had occurred to me during a study of my Rowland grating.

Boston, Mass.

ART. III. — *The Variation of Potential along a Wire Transmitting Electric Waves;* by C. A. CHANT.

I. *Introductory.*

HERTZ* was the first to explore a wire along which electric undulations were passing. His oscillator consisted of two sheet-brass plates 40^{cms} square, connected by a copper wire 60^{cms} long, in the middle of which was a spark-gap. Opposite and parallel to *one* plate was placed another of equal size, from which was led off a copper wire, the first meter of which was curved and the rest of it straight. As a detector he used his circular resonator, 70^{cms} in diameter. The nodes were well marked in two wires, the length of the straight portions of which were $5{\cdot}5^{m}$ and 8^{m}, respectively. The half-wave-length was determined to be $2{\cdot}8^{m}$.

These experiments were repeated and extended by Sarasin and de la Rive,† who somewhat increased the effect by using two wires led off from two plates placed opposite the oscillator plates, the resonator being held between them. These experimenters showed very clearly that the apparent wave-length measured along the wire was dependent purely on the size of the resonator, the wave-length being equal to eight times the diameter of the resonator.

Somewhat similar results were obtained by Waitz,‡ who used a circular resonator, to which were attached two wires, one joined near each terminal knob, and led off either parallel to each other or in opposite directions. In the former case, by sliding along a bridge laid across the wires, the sparks between the resonator knobs passed through maximum and minimum intensities; in the latter case, by hanging capacities on the wires and sliding them along, the sparks varied similarly. He worked with plate oscillators of two sizes, as well as cylindrical and spherical ones. He found that his minima depended entirely on the dimensions of his circular resonator.

The conclusion naturally drawn by Sarasin and de la Rive and Waitz from their experiments was that the oscillator emitted waves of various lengths, extending over several octaves; but this hypothesis has been shown to be improbable, a more satisfactory explanation being based on the fact that the oscillations of the oscillator are very rapidly damped, while those of the resonator are very persistent.§

* H. Hertz, Wied. Ann., xxxiv, p. 551, 1888. Electric Waves, p. 106.

† E. Sarasin and L. de la Rive, Archives des Sciences Physiques et Naturelles. Genève, xxiii, p. 113, 1890.

‡ K. Waitz, Wied. Ann., xli, p. 435, 1890.

§ See Poincaré, Les Oscillations Électriques, Art. 55 and fol. J. J. Thomson, Recent Researches, p. 340.

In Lecher's* experiments the exciter consisted of two sheet-metal plates, 40^{cms} square, joined by a bent wire 2^{m} long, with a spark-gap in the middle of it. Opposite each plate and parallel to it was another of the same size, from which ran long, straight, parallel wires. On the farther ends of these was laid a vacuum tube, and across the wires at different points were laid metallic bridges. When these were properly placed, namely, at the potential nodes, the tube at the ends lighted up. The wave-lengths he obtained, however, were not those proper to the exciter, but those of that part of the wire-system on that side of the first bridge next the plates, which was in resonance with the rest of the wire-system.

In Cohn and Heerwagen's† experiments with Lecher's method a condenser was added to the ends of the wires.

Blondlot‡ also experimented with parallel wires, but used an oscillator of quite different construction. In Lecher's arrangement the capacity is large compared to the self-induction; in Blondlot's the reverse is the case. The latter has the advantage that the damping is much diminished.

These "wire-waves" have been the subject of numerous investigations, a notable one being that by Drude.§ He found that the oscillator must be considered as composed of the Blondlot semicircular primary exciter, together with that portion of the secondary wire-system as far as the first bridge; and that when the bridges are properly placed there is resonance between this oscillator and the rest of the system. Very convenient forms of this apparatus are given by Coolidge‖ and Hormell.¶

Donle,** who used chiefly the Blondlot oscillator, joined the ends of the parallel wires with a glow-lamp. His aim was to diminish the wave-lengths, which he reduced to 130^{cms}. Coolidge's smallest wave-length was 12^{cms}.

In Rubens's experiments the exciter was of the Hertzian form, with plates 40^{cms} square. The two opposing parallel plates were but 10^{cms} square, though the smaller plates are not quite as efficient as those of equal size.†† From these smaller plates the parallel wires went out,—in this instance to a distance of 570^{cms},—and were explored by a bolometric method. Rubens‡‡ found that the oscillations along the wires were not

* E. Lecher, Wied. Ann., xli, p. 850, 1890.
† Cohn and Heerwagen, Wied. Ann., xliii, p. 343, 1891.
‡ R. Blondlot, Comptes Rendus, cxiii, p. 628, 1891.
§ P. Drude, Eine bequeme Methode zur Demonstration des electrischen Brechungsexponenten von Flüssigkeiten. Wied. Ann., lv, p. 633, 1895.
‖ W. D. Coolidge, Wied. Ann., lxvii, p. 578, 1899.
¶ W. G. Hormell, this Journal, xii, p. 433, 1901.
** W. Donle, Wied. Ann., liii, p. 178, 1894.
†† Drude, Physik des Aethers, p. 446.
‡‡ H. Rubens, Wied. Ann., xlii, p. 154, 1890.

the same as those of the oscillator; in other words, the oscillations were not forced along the wires, but were those natural to them.

These experiments were verified by Rutherford,* who substituted a magnetic detector for the bolometer, and found it equally sensitive.

In all these experiments it will be observed that the wave-lengths determined along the wires are not those proper to the oscillator, but are either due to the detector used or to the wires vibrating naturally.

In Birkeland's† and Jones's‡ researches the reverse seemed to be the case. The wire-systems were both similar to that of Sarasin and de la Rive, but the means of exploration were different. Birkeland examined the potential at various points of his wire, which was 30^{m} long, by measuring the length of the spark which leaped from it to an earth connection, the existence of the spark being indicated by a telephone receiver held to the ear. He obtained minimum points which varied as the period of the oscillator was changed, thus indicating that the measured wave-length depended on its period. These minima were unequally spaced, which irregularity was attributed to the damping of the waves and the loss on reflection at the ends of the wires; but the explanation does not seem entirely satisfactory.§

Jones used a thermal junction inserted at different points of his wire, which was 130^{m} in length, the effect being indicated by a low-resistance galvanometer in circuit with it. The oscillator was of the usual type, with plates 40^{cms} square, but the length of the connection between the plates is not given. Several well-defined maxima and minima were observed, and the wave-length was determined to be approximately $4{\cdot}3^{m}$. It is interesting to read that "several curious results were recorded for which no explanations were forthcoming."‖

It may be worth while to recall how the wave-length of Hertz's plate oscillator was determined. He obtained it with the aid of his circular resonator, but, as has been already remarked, the wave-length thus found is always eight times the diameter of the resonator. If, then, we could know when the resonator was exactly in unison with the oscillator, the wave-length could be deduced with considerable accuracy. But this is not at all possible; the resonance is far from being sharply defined. Indeed, Hertz says that the same resonator, of diameter 70^{cms}, was in resonance with three different oscillators. The first consisted of two spheres of diameter 30^{cms}, connected

* E. Rutherford, Phil. Trans. A, 1897, clxxxi, p. 1.
† Kr. Birkeland, Wied. Ann., xlvii, p. 583, 1892.
‡ D. E. Jones, Brit. Assoc. Report, 1891, pp. 561–2.
§ See Poincaré, l. c., p. 176. ‖ Nature, xliv, p. 454, 1891.

by a wire 70^{cms} long, with a spark-gap in the middle; the second, of two plates 40^{cms} square, joined by a wire 70^{cms} long with a spark-gap as before; the third had plates of the same size, but the wire was 60^{cms} long.*

Thus the wave-length emitted by each of these was taken to be the same, namely, 560^{cms}. Now the period and wave-length of the first oscillator have been found theoretically. Hertz† calculates the period to be 1·26 hundred-millionths of a second and the wave-length to be 4·6^{m}, while Drude‡ makes the latter 4·8^{m}. Both values differ considerably from that obtained by resonance. Again, the second and third oscillators differ considerably in period, though that of the second was found to be the same as that of the first. (See below.) We must conclude that the wave-length 5·6^{m} is not a very close approximation.

In the experiments to be described presently it will be seen that oscillators of the same type may differ decidedly in their behavior; that some seem able to force their vibrations upon a wire, while others cannot. The wave-length of an oscillator, the same as the third of the three just described, was concluded to be 5·88 meters.

II. *Experimental Arrangement.*

While engaged during the session 1900–1, in the Jefferson Physical Laboratory of Harvard University, on another investigation§ in which the magnetic detector was used, the fact that an electrical disturbance about a wire parallel to the wings of the detector exerted a strong action on the detector, was continuously and painfully evident. Indeed, the effect arising from the connecting wires at first entirely masked the true radiation from the oscillator.

This suggested the possibility of conveniently exploring the field along a wire by shortening the wings of the detector and then placing it close to the wire at various points in its length. The experiment was tried, but the demagnetization of the detector was small. However, on removing one wing and placing the other near the wire the effect was much greater and easily measurable.

But the action with one wing is not at all the same as with two. When the detector with two wings is placed along the wire, the surging in its helix and the consequent demagnetization is greatest at points where the current oscillation is great-

* Hertz, Electric Waves, Art. V, p. 81–2; Art. VI, p. 96–7; Art. VII, pp. 108 and 113.

† Hertz, l. c., p. 51 and p. 270 (note 6).

‡ Drude, Physik des Aethers, p. 397. See also J. J. Thomson, l. c., Arts. 289 and fol.

§ C. A. Chant, An Experimental Investigation into the "Skin"-effect in Electrical Oscillators, this Journal, xiii, p. 1, 1902. Phil. Mag., VI, vol. iii, p. 425, 1902.

est, i. e., at a current loop; the effect is least at a current node. With a single wing these results are exactly reversed,—the effect is greatest at a current node, which is, of course, a potential loop. This can be explained in the following way: The little wing and the portion of the wire just beside it act as a miniature condenser, and when there is a maximum variation of potential in the element of wire there will also be a maximum variation in the detector wing, which will cause currents to surge back and forth in the helix and so to demagnetize the iron core. At a current loop (or potential node), the variation in potential is a minimum, and so the detector when placed there will show minimum demagnetization. Indeed the indications of the magnetic detector should be precisely similar to those of the bolometer as used by Rubens.

An attempt was then made to force standing waves in a wire, and preliminary experiments seemed to show the possibility of determining the wave-lengths of oscillators in this way. Some measurements were made then, which, since returning to Toronto, have been considerably extended.

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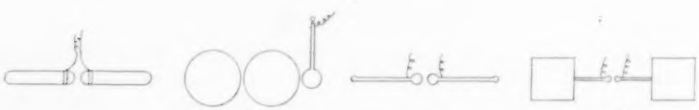

a *b* *c* *d*

The oscillators were of four kinds, illustrated in fig. 1. The cylinders of (*a*) were $2{\cdot}5^{cms}$ in diameter and $12{\cdot}5^{cms}$ long, with hemispherical ends; the spheres of (*b*) were of two sizes, namely, with diameters of 10^{cms} and 30^{cms}, respectively; the larger spherical ends of (*c*) were 19^{mm}, the smaller 6^{mm}, and the straight portion $4{\cdot}2^{mm}$, in diameter, while the length over all was $12{\cdot}5^{cms}$; in (*d*) is shown the ordinary Hertzian plate oscillator.

The sparks were produced by an induction coil capable of giving sparks $12{\cdot}5^{cm}$ long, and fed by five accumulators in series.

The interrupter was similar to that used in the other investigation. It consisted in a platinum-tipped rod, which, by means of a motor, was alternately plunged into and withdrawn from mercury, the surface of which was kept clean by a stream of water continually flowing over it. In series with this were a pendulum interrupter and a contact key. This key was depressed during any desired number of vibrations of the pendulum,—usually five swings,—during which time the coil was interrupted approximately sixty times. This number, of course, varied somewhat with the speed of the motor, but it did not change much during any series of readings.

The magnetic detector was the same as that used in the other research. It had twenty pieces of iron, 0·014^{cm} in diameter and 1^{cm} long, insulated from each other by paraffine, and wound over with ninety turns of fine insulated wire. It was mounted in the end of a glass tube, and all held on a small sheet of hard rubber by means of wax. It is shown one-half of natural size in fig. 2.

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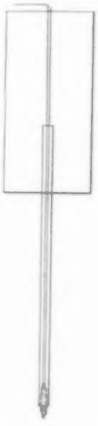

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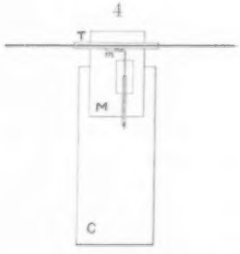


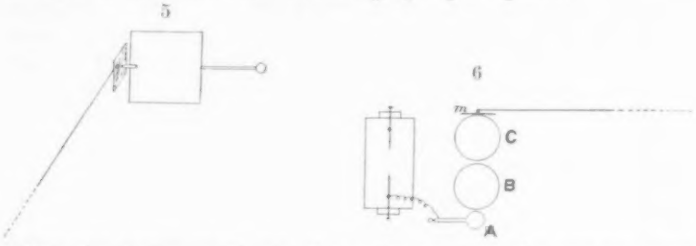
The magnetometer and telescope, as well as the method of placing the detector behind the magnetometer, were as described in the former paper.

The manner of producing the oscillations along the wires is shown (for the cylinders) in fig. 3. AB is a long straight wire (0·7^{mm} in diam.), ending at A in a small knob 6^{mm} in diameter, which was separated from an end of one of the cylinders by a piece of mica, M, usually 0·15^{mm} thick. By this means the surgings on the cylinders were impressed upon the wire, which was explored by placing the little detector near it at different points in its length.

Since the magnitude of the effect depends on the distance the detector wing is held from the long wire, it was necessary to regulate this accurately. To do so a small glass tube, about 4^{cms} long, T, fig. 4, with bore just great enough to allow it to slide over the wire, was taken, and to the outside of this was fastened a bit of finely-drawn tubing, *m*, into which the wing fitted snugly. In all the experiments the wing was 1^{cm} long.

The glass tube was attached to a piece of hard rubber (or mica), M, which, again, was cemented to the top, C, of a carriage which moved along beside the wire.

Thus, to examine any portion of the wire, the carriage was moved along to the required place, the distance of which from the end of the wire was measured by a scale on the ways on which the carriage moved. The detector was magnetized, then placed in its pocket beside the glass tube, and sparks made to pass at the oscillator for a certain length of time. The detector was then removed and examined by the magnetometer. This process was systematically carried out, beginning at the end of the wire and advancing by equal spaces.



For the linear oscillator, shown in fig. 1, *c*, the arrangement was precisely the same as for the cylinders. For the Hertzian oscillators, fig. 1, *d*, a rounded end was given to one of the plates by taking a piece of brass rod 6^{mm} in diameter and about 2^{cms} long, rounding the ends, and then making a slit in one end, which allowed it to be slipped over the plate. This is shown in fig. 5.

The arrangement for the spherical doublet is shown in fig. 6. When the coil was in action sparks passed between A and B and B and C, and the oscillations on the sphere C were transmitted to the wire across the mica plate, *m*.

The wires used were quite short, ranging from 1 meter to 8·6 meters in length.

III. *Results of Experiments.*

It will be convenient to divide the results into two parts: A, those obtained with the oscillators *a*, *b*, *c*, of fig. 1; and B, those with the Hertzian oscillators.

A. *Cylindrical Oscillator* (*fig. 1, a*).

In fig. 7, *a*, *b*, *c*, are shown curves obtained with the cylindrical oscillator, which was made of sheet platinum on a wooden form with well-shaped hemispherical ends. Here, as always, the greatest variation in potential was at the end of the wire. It gradually fell until a minimum was reached at approximately 20^{cms} from the end, and after another rise it dropped again to a minimum at approximately 60^{cms}. Each of the last two curves gives a half-wave-length of 40^{cms}, the first one 38^{cms}, or a mean wave-length for the oscillator of approximately 79^{cms}.

In every instance the actual readings are shown.

Linear Oscillator (fig. 1, *c*).—Curves obtained with this oscillator are shown in fig. 7, *d*, *e*. Curve (*d*) is the mean of

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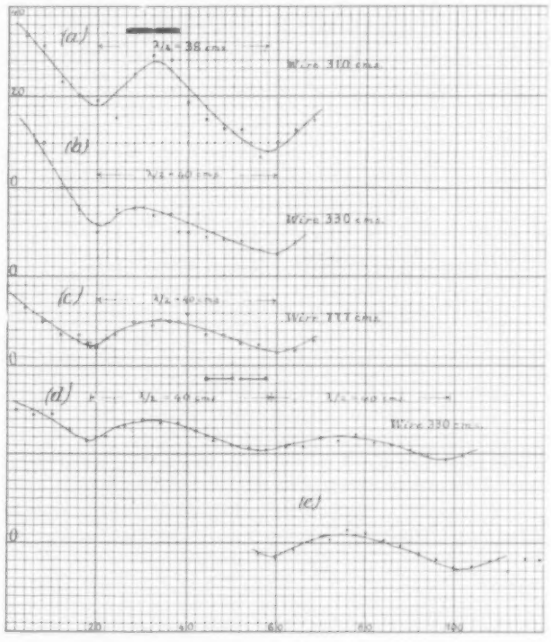


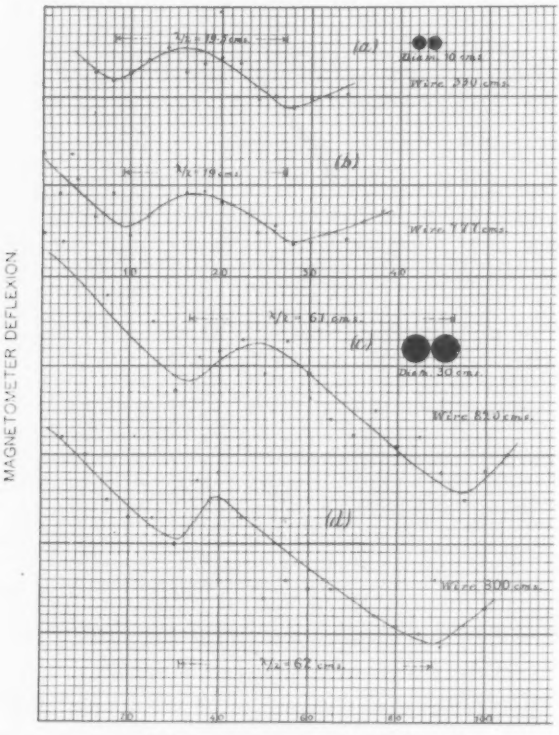
two sets of readings with five swings of the pendulum. The mean of five sets, each of two swings, gave the same minima, though the curve was not so good. Curve (*e*) is a repetition of the second portion of the readings; it is the mean of two sets of five swings each.

Here three minima are easily seen at 19, 59, and 99^{cms}, respectively, from the end; and the wave-length is thus approximately 80^{cms}.

Spherical Doublet (fig. 1, *b*).—Curves for this oscillator are given in fig. 8. It was much more difficult to get consistent series of readings with it. Curves (*a*) and (*b*) are for the 10^{cm} spheres. The half-wave-lengths deduced are, respectively, 19 and 19·5^{cms}, with a mean wave-length of 38·5^{cms}. Curves (*c*) and (*d*) are for the 30^{cm} spheres. The half-wave-lengths from these are 61 and 62^{cms}, respectively, with a mean wave-length of 123^{cms}.

These curves are not as smooth as the former ones, but are perhaps as good as one should expect with so dead-beat an oscillator.

8



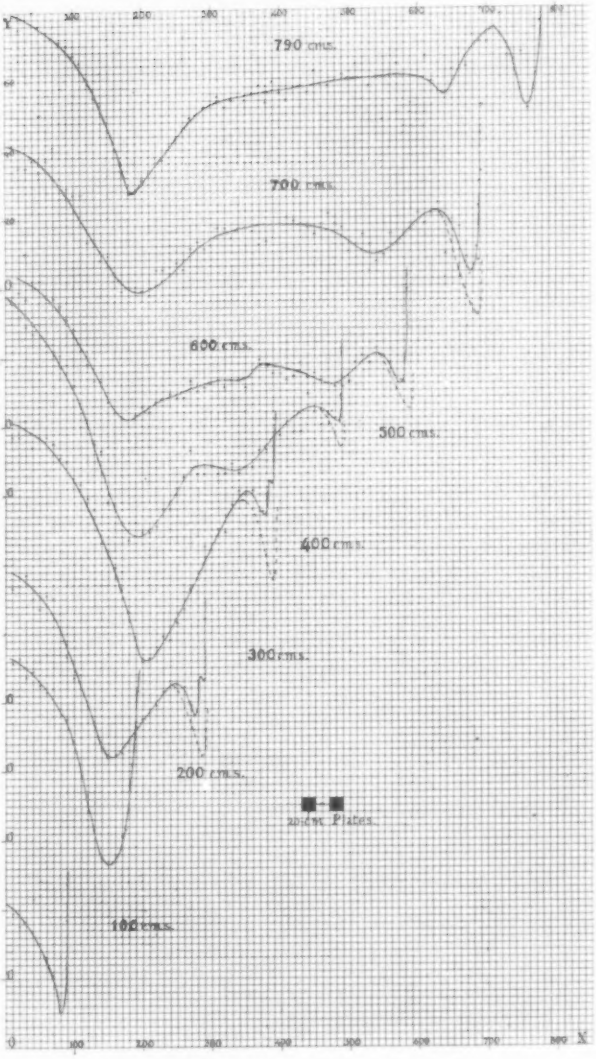
From the results with the 10^{cm} spheres the ratio of wave-length to diameter is 3·85, while with the 30^{cm} spheres this ratio is 4·1.* The theoretical value given by J. J. Thomson† is 3·6. Further exploration of the wire revealed no more minima.

* It may be interesting to compare values of this ratio obtained by other experimenters. Some are given in the following table, taken from a paper by Hull in the Physical Review, vol. v, p. 231, 1897 :

Diam. in mm.	λ in mm.	λ/Diam.	Experimenter.
80	200	2·50	Righi
37·5	106	2·83	"
8	26	3·25	"
7·8	18·4	2·36	Bose
19·3	91	4·71	Hull
9·3	43	4·62	"
7·9	40	5·18	"

† J. J. Thomson, l. c., p. 370.

9


790 cms.
700 cms.
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500 cms.
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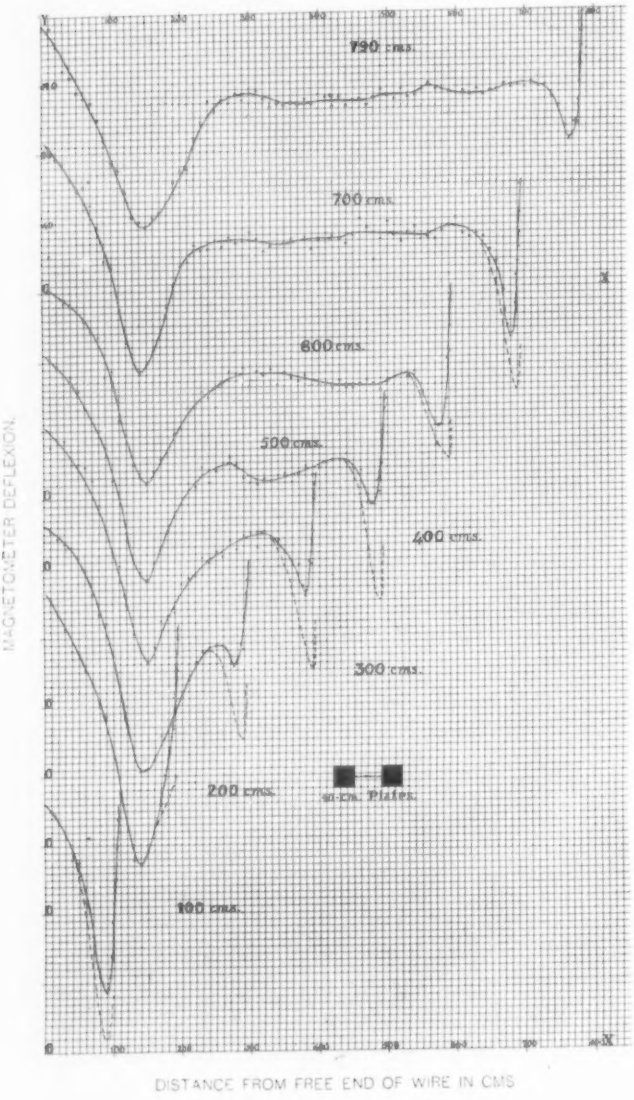
100 cms.
Incident Plates
MAGNETOMETER DEFLEXION
DISTANCE FROM FREE END OF WIRE IN CMS.

10


790 cms.
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200 cms.
100 cms.
40-cm. Plates.
MAGNETOMETER DEFLEXION.
DISTANCE FROM FREE END OF WIRE IN CMS.

TABLE OF MINIMA.

Distance, in centimeters, of minima from free end of wire.

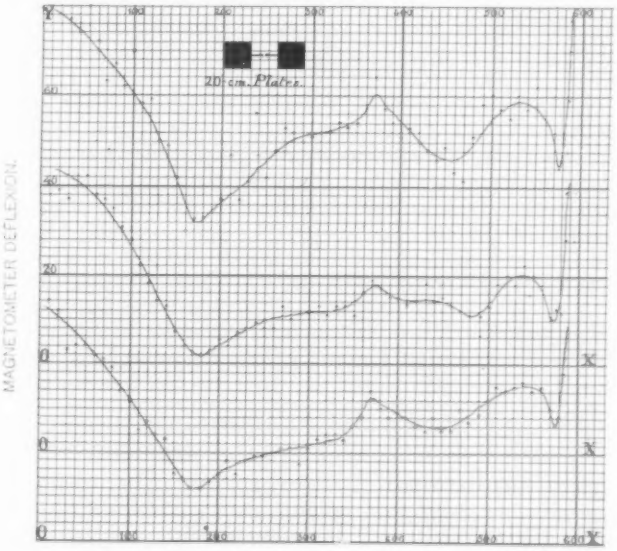
Size of Oscillator Plates.	Wire 860cms.	Wire 850cms.	Wire 840cms.	Wire 830cms.	Wire 820cms.	Wire 810cms.	Wire 800cms.	Wire 790cms.	Wire 700cms.	Wire 600cms.	Wire 500cms.	Wire 400cms.	Wire 300cms.	Wire 200cms.	Wire 100cms.
10cms.								187..635 ..780 ..655 ..781 ..625 ?..780 187.. 193.. ..645 ..781		175.. 178.. 178.. 177..		197.. 197.. 199.. 203..			
15cms.								188..635 ..780 185..618 ?..780 182..		183.. 178.. 182.. 186..		148..205.. 152..197.. 150..200.. ..203.. 152..			
20cms.	200..	192..	182..710..	190..675..820	198.. 200..	208..645.. 205..650..	188..620 ?..790 190..650 ..790	193..638..780	185.. 540..690 245..345..542..690 170.. 175..	177..460..590 175..480..590 175..450..590 175..	207..350..490 195..347..490 195..365..490 188 ?.. 195 ?..	202..390 210..390 206..390	154..290 155..290 152..	150 148	85 85
25cms.								180..655..780 186..630..780 190..		177.. 182.. 184..		205.. 208.. 207.. 200..			
							Mean	187·1		178·8		202·6			
30cms.								130..230..585..780 140..220..620..780 130..		125 .. 142 ?.. 119 ..200 ?.. 136 ..		124..196..260.. 140..200..262.. 142..215.. 125..207..271.. 127..197..272.. 122..200..260..			
35cms.								132..630..775 135..620..770 133..		134.. 134.. 132.. 132..		133.. 132.. 132.. 131..			
40cms.	148..735 ?..	150..740 ?..	145..750..	150..745..	150..720 ?..	150..645.. 148..655..	150..650..790	150..350..625 ?..780 150..345..—— ..780	150..360 ..550..688 142..355 ?..550..690 144..	154..430 ..590 146..430 ..590 147..430 ?..590 150..440 ..590	152..355 ?..490 150..355 ..490 150..335 ?..490 154..	149..387 147..387 149..	143..290 150..290 150..	140 138	82·5 82·
50cms.										170.. 170.. 172.. 170..		170.. 177..			

B. *The Hertzian Oscillators.*

With the Hertzian oscillators the results were quite different from those just given, and indeed they differed considerably among themselves.

The first oscillator tried had sheet-zinc plates 40^{cms} square, with the straight wire between them 60^{cms} long; and the wire transmitting the waves was 860^{cms} long. One minimum was very well marked, but there were no more clear ones. Then a

11



second oscillator, with 20^{cm} plates, and otherwise of just half the size of the former was tried, but the minimum, instead of being half the distance from the end, was much farther from it. This led to the making of additional oscillators, with plates 10, 15, 25, 30, 35, 50^{cms} square, respectively, and with the wires between of proportional length. The spark-knobs were 19^{mm} in diameter, the same knobs being used with all the oscillators.

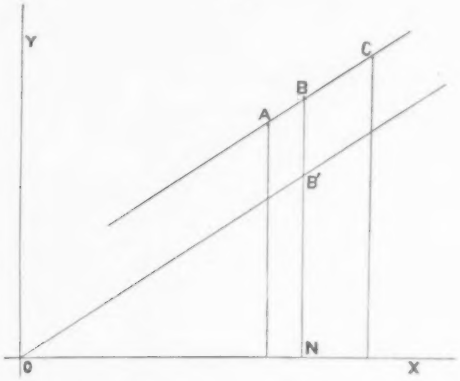
Using these oscillators, readings were taken with wires from 100 to 860^{cms} long; and the results obtained are exhibited in the accompanying table and curves. In the table, the positions of the minima are given by stating their distances in centimeters from the free end of the wire. There was always one more marked than the others, and this one, indicated in the

table by more prominent type, will be referred to as the *chief* minimum.

In fig. 9 are shown readings and curves obtained with the 20^{cm} oscillator with various lengths of wire, and in fig. 10 are similar readings with the oscillator of double the size, i. e., with 40^{cm} plates; while in fig. 11 is shown a series of three successive curves given by the 20^{cm} oscillator with the same length of wire. These illustrate the method moderately well.

Remarks on the Table and the Curves.—A glance at the table will show that the oscillators used can be divided into two distinct groups, the first including the four smaller ones, and the second the three larger ones, while the oscillator with

12



30^{cm} plates lies between the two groups. The results with each group are consistent among themselves, while the 30^{cm} oscillator behaved in a very irregular manner.

For the first group (the smaller ones), the positions of the minima for any particular length of wire are independent of the size of the oscillator, i. e., they depend only on the wire's length. In this case the oscillator does not force its period on the wire.

In the second group, on the other hand, the positions of the minima depend only on the size of the oscillator, not at all on the length of the wire.

The conclusion seems natural that, in this latter case, the distance of the minimum from the free end is one-quarter of the wave-length of the oscillating system. The values of this quarter-wave-length deduced from the table are:

For	35^{cm}	oscillator	$132{\cdot}7^{cms}$	(mean of	11 results).
"	40	"	147·1	"	21 "
"	50	"	171·5	"	6 "

Now it is possible that the proximity of the wire to the oscillator may have the effect of virtually increasing the size of the oscillator, and if such is the case all the quarter-wave-lengths so determined are too great. According to Poincaré's* deduction from the homogeneity of the fundamental equations, the wave-length of an oscillator or resonator varies directly with its linear dimensions. In fig. 12 the points A, B, C have abscissæ proportional to the dimensions of the three larger oscillators and ordinates proportional to the quarter-wave-lengths given above. It is seen that they lie very approximately on a straight line, but this line does not pass through the origin. Let us now draw a line parallel to it and passing through the origin. The ordinate B′N of this line, corresponding to the 40^{cm} oscillator, has a length of approximately 103^{cms}. Thus if the principle of direct proportionality, stated by Poincaré, held without limit to its application, the arrangement of the wire as in the experiments should be equivalent to adding 44^{cms} to the quarter-wave-length of each of the three larger oscillators. On the other hand, the fact that varying the length of the wire from 3^{m} to $8{\cdot}6^{m}$ had no effect on the position of the minimum, seems to show that the wire did not act in the manner referred to. In other words, the quarter-wave-lengths given are proper to the oscillators.

Experiments with the first and second Hertzian oscillators, referred to above, gave the following values for the quarter-wave-length:

For 40^{cm}	plates,	straight connection	70^{cms}	.....	$154{\cdot}4^{cms}$
30	spheres,	"	"	.....	153·9

These are practically identical.

For all wires of three meters and upwards in length there is a well-defined minimum between 10 and 15^{cms} from the end next the oscillator. In figs. 9, 10 is shown a portion of each curve near the oscillator in continuous line, and also in broken line. In this neighborhood the oscillator exerted a strong action directly on the detector. In order to allow for this, readings were first taken as usual (shown by continuous line); then the wire was removed and readings taken at exactly the same points. These latter were then subtracted from the former, and the broken line shows the result. Here it is assumed that the action of the oscillator and of the wire singly are equivalent to the two together. To examine this minimum more closely readings were taken at intervals of one centimeter. There is no doubt of its existence; it is about 10^{cms} from the end for the smaller oscillators and slightly

* Poincaré, Les Oscillations Électriques, Art. 53.

farther for the larger ones. I find it difficult to give the significance of this.

Other minima were found, but they were not so well-defined. They are, no doubt, due to natural oscillations of the wire, but they are hard to identify.

For the wires 300 and 400^{cms} long the chief minima are at the middle points.

The question of the dependence of the positions of the minima on the detector is interesting and important; and that there is no such connection was shown in the following way. A second helix, similar to that of the detector, was soldered to the free wire running up beside the one bearing the wing, thus practically doubling the capacity and inductance; but there was no displacement of the minima. The period of the detector must be many times that of the oscillators.

In the near future I hope to apply the magnetic detector to the exploration of much longer wires, in which case the phenomenon of standing waves should be more distinctly shown.

University of Toronto, Toronto, Canada.

ART. IV.—*Rickardite, a New Mineral;* by W. E. FORD.

THE new mineral to be described in this paper was first brought to the writer's attention by Mr. T. A. Rickard of New York. A qualitative examination proved that it contained copper and tellurium, and no such combination having been hitherto described, the mineral seemed worthy of investigation. Through the courtesy of Mr. Rickard, sufficient material was afterward obtained for making a quantitative analysis, the results of which are given below.

Rickardite occurs at Vulcan, Col., in the Good Hope mine owned by Dr. Loui Weiss. The vein mineral is chiefly pyrite, with which occurs native tellurium in unusually large masses, some of which measure fully three inches across. Other associated minerals are petzite, berthierite in imbedded prisms resembling stibnite, and a greenish brown micaceous substance, perhaps roscoelite. A large body of native sulphur also was found in the vein. Rickardite itself occurs in small lense-shaped masses, generally rather intimately associated with native tellurium.

The material for analysis was broken up and carefully gone over by hand to free it from any adhering gangue and only perfectly clean and homogeneous fragments were used. The method of analysis was simple. The powdered mineral was oxidized by nitric acid, which was subsequently removed by evaporation with sulphuric acid. To the strong sulphuric acid solution a liberal amount of hydrochloric acid was added and then sulphur dioxide gas was led into the solution, which precipitated the tellurium in metallic form. This precipitate was filtered onto a Gooch crucible, dried in the air bath at 100° C. and then weighed. In the filtrate copper was precipitated by hydrogen sulphide and determined as cuprous sulphide by igniting in a stream of hydrogen. Careful tests were made for gold, silver, lead, selenium, sulphur, arsenic and antimony with only negative results.

The analysis follows:

	I.	II.	Average.	Atomic ratios.
Cu=	40·68	40·81	40·74	·6469=4·00
Te=	59·36	59·06	59·21	·4737=2·93
Total	100·04	99·87	99·95	

These results give the ratio Cu : Te=4·00 : 2·93, or very nearly 4·00 : 3·00, and the formula for rickardite therefore is Cu_4Te_3. This gives as the theoretical composition of the mineral, Cu=40·51 ; Te=59·49, which agrees very closely

with the analytical determinations. Rickardite is therefore not only a new mineral but also a new type of telluride, for no such four to three relation between metal and tellurium has hitherto been noted in the group of tellurides. The mineral may be regarded as consisting of one molecule of cuprous telluride and two of cupric telluride, $Cu_2Te.2CuTe$.

Rickardite has an unusual and beautiful purple color, which rivals in intensity the deepest purple tarnish ever seen on chalcopyrite or bornite. The color, however, in the case of Rickardite is not due to any tarnish, for it shows on a fresh fracture and the powder of the mineral, even when ground very fine, is of the same deep color. The mineral is massive in character with an irregular fracture. Its hardness is 3·5 and its specific gravity was determined as 7·54. It is fusible at 1 and gives a pale azure blue flame color tinged in the outer parts with green. Alone on charcoal before the blowpipe it gives a white coating of TeO_2 and fuses to a brittle globule of copper telluride. Fused with sodium carbonate and borax on charcoal it gives a coating of TeO_2 and a brittle globule of telluride, yielding only with considerable difficulty a malleable globule of copper. Roasted in the open tube the mineral fuses to a semi-transparent mass of brown color, which is apparently some combination of the oxides of tellurium and copper, and only a faint sublimate of TeO_2 is formed on the walls of the tube. Heated in the closed tube it fuses and undergoes no further change. Heated in concentrated sulphuric acid it gives the characteristic reddish-violet color of tellurium. When dissolved in nitric acid, the solution neutralized with ammonium hydroxide gives the deep blue color of copper.

It is a pleasure to name the mineral Rickardite after Mr. T. A. Rickard, the editor of the Engineering and Mining Journal of New York, who obtained the material for investigation and supplied the data as to its occurrence. Thanks are also due Dr. Weiss of the Good Hope mine, who has been careful to secure all specimens which might be of scientific interest. In conclusion, the writer wishes to express his indebtedness to Prof. S. L. Penfield for his constant advice and assistance during the preparation of this article.

Sheffield Laboratory of Mineralogy,
Yale University, New Haven.

Art. V.—*An Occurrence of Free Phosphorus in the Saline Township Meteorite;* by Oliver C. Farrington.

On drilling into the Saline Township meteorite* recently for the purpose of breaking off a piece, a white "smoke" was observed by the writer to rise from the drill hole when a depth of a little over two inches (5·5^{cm}) had been reached. This "smoke" had a pungent, garlic-like odor which was recognized as similar to that of white phosphorus. It was more pungent and resembled the odor of burning arsenic to some extent, but on the whole suggested that of phosphorus more. It was at once surmised that phosphorus might exist in the free state in the meteorite, and the supposition was soon confirmed by the following tests:

1. On shielding the eyes from the light and looking into the drill hole, a luminous spot could plainly be seen at the bottom. This spot on further observation showed itself to be actually made up of two. One of these was fixed and central and the other moved around it, making a revolution every two or three seconds. This motion corresponded to the swirling movement with which the fumes rose from the hole and doubtless represented the manner of supply of air to fresh portions of the phosphorus.

2. On holding a strip of paper saturated with silver nitrate in the fumes it turned black in a few moments.

3. On treating some of the powder from the drilling with nitric acid and adding the solution so obtained to ammonium molybdate, the familiar yellow precipitate of ammonium-phospho-molybdate was produced.

The fumes continued to rise from the hole for about two hours when they gradually diminished in volume and disappeared. The odor could, however, be detected eighteen hours afterward. These observations were confirmed by several of my associates. No effort has as yet been made to obtain a quantitative determination of free phosphorus in the meteorite, nor is it likely that results of any particular value could thus be gained. Two holes were drilled the same depth as the first in other parts of the stone, but from neither was any repetition of the above-named phenomena observed. The phosphorus is (or was) probably, therefore, only locally distributed and in small quantity. The stone where broken at the end of the hole first drilled shows a spot about half an inch in diameter differing considerably in color from the rest of the stone, being

* For a brief account of the fall and general characters of this meteorite see Science, N. S. vol. xvi, p. 67, July 11, 1902.

brownish white in contrast to the greenish black hue of the remainder. This portion may prove on further examination, therefore, to be differently constituted. The properties above described are those of free phosphorus, however, and the observations leave no doubt that it existed in the meteorite. This seems to be the first known instance, then, of finding this element existing in the free state in nature.

The occurrence serves to point several conclusions regarding the origin of meteorites, which, while they do not differ from those now generally held by students of these bodies, emphasize opinions which have at times been disputed. First, the meteorite was not formed upon the earth. Second, free oxygen was not present where it was formed. Third, the interior of the meteorite cannot have been subjected to any high degree of heat since its aggregation in the solid state.

Field Columbian Museum,
Chicago, Ill.

OGDEN NICHOLAS ROOD.

Ogden Nicholas Rood, Professor of Physics in Columbia University, New York, died at his residence in New York, on Wednesday, November 12, of pneumonia, after an illness of but a few days. He was at the head of the Department of Physics, and the senior officer in the faculties of the university.

Professor Rood was born in Danbury, Connecticut, Feb. 3, 1831, and was the son of Rev. Anson Rood, a Congregational clergyman, and Aleida Gouverneur (Ogden) Rood. He entered Yale College in 1848 as a member of the Class of 1852, but did not remain longer than one year, subsequently entering Princeton College, where he graduated in 1852. The autumn of this year he spent in New Haven, pursuing scientific courses of study as a graduate student, in the Department of Philosophy and the Arts, of Yale. Although his name appears upon the college catalogue as a member of this department for the two college years 1852–3 and 1853–4, he spent but a portion of this time in New Haven. During several months in the early part of 1853 he was at the University of Virginia, acting as assistant to Professor J. Lawrence Smith. Later in the same year he was for some months in New York, as the assistant of Professor B. Silliman, Jr., who was in charge of the Chemical, Mineralogical and Geological Department of the Crystal Palace, in that city. His scientific tastes had already declared themselves at this time, and his earliest contributions to this Journal were two papers, which he had read before the Berzelius Society of Yale, and which, even thus early, foreshadowed the direction his later studies would take. The first was "On the *Paramecium aurelia*," and gave an account of the microscopic study of the organism. The second was "On a method of exhibiting the Phenomena of Diffraction with the Compound Microscope." Both were published in 1853.

The four years, from 1854 to 1858, were spent in Europe at the universities of Munich and Berlin, in the further prosecution of his scientific studies. On his return to this country, in 1858, he accepted the position of Professor of Chemistry and Physics in Troy University, which he occupied until 1863, when he resigned. The institution had been suffering from lack of resources, and finally ceased to exist. Not long after this he was elected Professor of Physics in Columbia College, entering upon his duties early in 1864. This position he continued to hold during the remainder of his life.

Professor Rood was a born investigator, full of enthusiasm for scientific studies, with an uncommonly clear perception of

the principles involved in physical phenomena, and a keen intuition of the experimental conditions and methods leading to discovery. He was especially apt in the use of simple means for the study of the problems which interested him, often reaching results of great importance and novelty by the skillful combination of pieces of the most ordinary materials, such as are found in the physical laboratory. While apparently caring little for the exhibition of mechanical expertness, or for the attainment of mere elegance of design or finish, he possessed constructive faculties of a high order, in the adaptation of an apparatus for the purpose he had in view. Many of his most striking researches were conducted with scarcely any use of the standard instruments of the laboratory, his experiments being carried out with means improvised for the occasion, and gradually developed to greater and greater elaboration, as new suggestions came to him in the course of the work. In many cases this resulted in notable improvements of familiar apparatus, and the production of instruments of unexampled sensibility, and the attainment of a degree of precision far beyond anything hitherto reached. Excellent examples of this are seen in his improvement of the horizontal pendulum, by which he was enabled to detect and measure changes of dimension in solid bodies as small as the ten millionth part of an inch; in his modification of the Sprengel pump, by which he was able to carry the exhaustion to degrees almost unlimited, and to measure tensions as low as the four hundred millionth of an atmosphere; and finally, in the last research of his life, in which, by the use of an electroscope of the most elementary simplicity, he succeeded in measuring resistances of hundreds of thousands of megohms, and detecting peculiarities of insulating bodies hitherto unknown.

After entering upon his scientific career Professor Rood displayed great activity, and was a frequent contributor to this journal, where most of his papers were published. The number of titles of his communications is about seventy, not counting various minor contributions and notices. Though many of them are quite brief, they would be sufficient, in the aggregate, to form a volume of several hundred pages. The number and variety of these papers forbids anything like a full enumeration here, but some of the more characteristic may be briefly mentioned. While at Troy University he devised certain adaptations of the compound microscope for measuring the angles of crystals, and indices of refraction; studied the stauroscope of Von Kobell, and made new applications of it; observed the singular contraction of the muscles caused by contact with rapidly vibrating bodies, resulting in

a kind of temporary cramp similar to that produced by electric shocks; made many experiments upon the best forms for elongated projectiles, and demonstrated the superiority of American rifled firearms, and American marksmanship; devised a method of producing stereographic pictures by hand; discussed Dove's theory of luster, and devised many new experiments for producing it; studied the practical application of photography to the microscope, and showed how it might be used to determine the character of the minute markings upon diatoms.

The years from 1864 to 1869, after his settlement at Columbia College, were comparatively uneventful so far as publication was concerned, doubtless owing to the great demands of his new position. But, shortly after, a series of valuable researches was begun, and, throughout the rest of his life, contributions appeared in rapid succession. During this period he investigated the nature and duration of the discharge of a Leyden jar connected with an induction coil, and determined with an accuracy hitherto unattained the duration of the bright spark from a jar of small capacity. This work was resumed later, and he showed that the bright spark lasted for a period not longer than forty billionths of a second. He also, in connection with this research, studied the question of the amount of time of illumination necessary to vision, finding that a duration of four billionths of a second was sufficient for distinct vision. The experience gained in these experiments led him to study the character of lightning, using for the purpose a rotating card-board disk, which in his hands proved an efficient instrument of measurement in many applications. He thus, for the first time, determined the duration of the flashes, finding an average value of the five hundredth part of a second, but subject to great variations. He also showed the multiple character of the flashes, and that they often terminated in a single isolated discharge of so short duration as to be, in comparison with the others, practically instantaneous. In this period also were carried out the experiments with the horizontal pendulum, and the Sprengel pump, already referred to, and later the work upon the measurement of high resistances.

He had at intervals been much interested in the study of color, and made many experiments in the measurement of the intensities of colored lights. His first efforts in this direction were made by the help of the rotating disk, in a comparison of the gray from the black and white sectors of variable proportion, so adjusted as to have the same apparent brightness as the object studied. His skill in experimenting enabled him to make consistent observations, and he obtained valuable quantitative results. This subject was a favorite one with him,

and he recurred to it again and again. He was ultimately fortunate in discovering, in 1893, a novel and original photometric method which is independent of color, and which depends upon the shock which the retina receives when one illuminated surface is quickly withdrawn and replaced by another of different brightness. The flickering effect thus produced disappears when the two lights are of equal intensity. This idea he further elaborated later, and in 1899, he published in this Journal an article upon the Flicker Photometer, with a more complete description, and showed by elaborate tests and verifications that the accuracy attainable with this instrument, in comparing differently colored lights, is about the same as for white, or like colors, in the ordinary photometer. He applied it also with great effect in the study of color-blindness, and brought out, with striking emphasis, the interesting fact that eyes supposed to be normal differ greatly in their perception of colors, and that it is rare to find two persons who agree in their color vision.

Another subject which received much attention from him was the study of the character of various complex colors, especially those of the different pigments, and he devised a system by which it was possible to express the composition of such colors by the proportion of certain standard colors in their make up, thus for the first time introducing definite quantitative methods in the study of color and color-contrasts.

The results of Professor Rood's studies of color for many years especially fitted him to write a treatise upon the subject, and in 1879 he published a volume entitled "Modern Chromatics, with Applications to Art and Industry" (New York, D. Appleton & Co.), it being one of the volumes of the International Scientific Series. To the title, in a later issue, were added the words, "Student's Text-Book of Color." This addition suggests the purpose and scope of the work, which was intended for the inexperienced student interested in the practical uses of color, as well as for those familiar with the principles of optical science. It is a happy example of clear and simple exposition, that is at the same time of a strictly scientific character. The book is full of interesting suggestions, and the results were carefully verified by innumerable novel and ingenious experiments which were original. It forms an indispensable hand-book for the artist, as well as for those interested in the practical applications of color.

It may be added that Professor Rood's work upon this book was greatly facilitated by his own experience as an artist. As early as his residence in Munich he had practiced painting in oil, and attained a high degree of proficiency. He had great skill in drawing, and became expert in painting in water-colors,

some of his pictures having been shown at the exhibitions of the Academy of Design in New York.

In 1865 Professor Rood was elected to membership in the National Academy of Sciences, which was founded two years before. He was therefore one of the senior members of the Academy, at whose meetings he often presented papers of great interest. He was a Fellow, and, in 1869, Vice President, of the American Association for the Advancement of Science. He was also a member of the American Philosophical Society, and of various other associations, scientific and social.

At the Bicentennial Celebration of Yale University in October, 1901, the degree of Doctor of Laws was conferred upon Professor Rood "as a pioneer of American Science," an honor seemingly somewhat tardily bestowed. But it is understood that his aversion for public ceremonials and display, and possibly slight valuation of academic distinctions, had led him previously to decline similar honors on more than one occasion.

In his personal qualities Professor Rood was a man of strongly marked individuality. In figure and manner there was much of native distinction, while his countenance, often grave, even sombre, and piercing eye, conveyed the impression of great intellectual force and keenness. He had an unusual power of piquant and interesting conversation, which was displayed most agreeably in the company of congenial friends. His grave demeanor was often a mask for a vein of humor which was one of his strong characteristics, and which, if often mischievous, and sometimes rather grim, was not often misapprehended by those who knew him well. His detestation of shams and commercialism in science was intense, and his expression of it both frank and forcible. While apparently not greatly caring for general social activities, and in his devotion to his scientific occupations having somewhat the way of a recluse, he was most hospitable and cordial to his scientific friends, and did many acts of spontaneous and unexpected kindness, which revealed the warmth of feeling hidden beneath his reserve. To his younger colleagues especially he showed great friendliness, and his generous estimation of their work, and cordial appreciation, were most encouraging and helpful. To all such his departure leaves a permanent sense of loss, as it must to the university he served so long and honorably.

Professor Rood was married, in 1858, to Miss Matilde Prunner, of Munich, who survives him, with three daughters and two sons.

Arthur W. Wright.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Properties of Radium.*—Giesel has recently announced that radium gives a pure carmine-red flame-color, which gives a brilliant spectrum. This flame-spectrum is remarkably different from Demarçay's spark-spectrum, since two broad, intense lines occur in the orange-red while the spark-spectrum shows only very faint lines in this region. He has observed also that pure radium bromide, as well as the salt containing barium, gives off bromine continually, while the air in contact with the salt becomes ozonized. This liberation of bromine is accompanied by the appearance of an alkaline reaction (radium hydroxide) and the gradual formation of radium carbonate by the action of atmospheric carbon dioxide. When radium bromide thus gradually decomposes, a gas is produced, and the crystals contain a part of it in an occluded condition. Upon dissolving the crystals in water they become milky at first and give off the gas with a crackling sound. A solution of radium bromide behaves similarly to the solid substance; it becomes yellow from free bromine, which remains dissolved, and a colorless gas is constantly evolved. It seemed probable to Giesel that this gas was hydrogen (although oxygen rather than hydrogen would be expected to accompany bromine), but a sample of it when mixed with one-third of its volume of oxygen did not explode when brought into contact with a flame. It is not yet known what this gas is, but a spectroscopic examination of it is to be made. As would be expected from the investigations of Curie, the gas is exceedingly active, causing phosphorescence and darkening the glass with which it comes in contact. It is suggested that this may be a new gas derived from radium, and that it may be connected with the remarkable inductive action of this substance. It was found that pure anhydrous radium bromide at first phosphoresces with a magnificent bluish light which gives a continuous spectrum. The phosphorescence diminishes after a day or so in consequence of the substance becoming colored, but the activity can be temporarily restored by heating and thus decolorizing the salt, although the phosphorescence becomes continually weaker. The pure radium bromide used in the experiments that have been mentioned gives off Becquerel's rays to a marked degree. Previously fused alkali-metal halides are colored by them in a few minutes.—*Berichte*, xxxv, 3608. H. L. W.

2. *Radio-activity of Uranium.*—It was shown some time ago by Crookes that by simple chemical means uranium could be obtained which was inactive to the photographic film, while the whole of the photographic activity could be concentrated in a small residue, not containing uranium, to which the symbol UrX was given. Frederick Soddy has now confirmed Crookes's

results as far as the photographic activity is concerned, but he finds, when the products are tested by means of the electrometer, that the UrX part is almost inactive while the uranium part retains its activity. The conclusion is reached, agreeing with the observations of Rutherford, that uranium possesses two distinct kinds of radiation, one of which (α) is absorbed very readily even by gases and the other (β) is very penetrating in its nature. It was found that after the cathodic (β) rays have been removed by chemical means they are gradually regenerated in the uranium salt.—*Chem. News*, lxxxvi, 199. H. L. W.

3. *Radio-activity of Thorium.*—In connection with the description of very elaborate researches on the subject, Rutherford and Soddy mention some interesting facts in regard to thorium radio-activity. Besides being active in the same way as uranium compounds, the compounds of thorium continuously emit a gas which possesses the property of temporary radio-activity. This emanation is the source of rays which ionize gases and act upon photographic films. The emanation excites radio-activity on all surfaces with which it comes in contact, and such surfaces behave as if they were covered with an invisible layer of intensely active material. If thoria is exposed to a strong electric field, the excited radio-activity is entirely confined to the negatively charged surface, and in this way it is possible to concentrate it on a very small area. The excited radio-activity is removed by rubbing, or by the action of acids. If the acids be then evaporated, the radio-activity remains on the dish. It appears from these facts that minute quantities of special kinds of matter in the radio-active state are given off by thorium compounds.—*Phil. Mag.*, 1902, 370. H. L. W.

4. *Metallurgical Laboratory Notes;* by Henry M. Howe. 8vo, pp. 140. Boston, 1902 (Boston Testing Laboratories).—This is a course of laboratory instruction for students. The author, very wisely it seems, has avoided the attempt to reproduce industrial processes as a whole, but has aimed to teach the underlying principles. His reasons for this plan are well put as follows: "For the details of practice are learnt inevitably, spontaneously, accurately and with the greatest ease in practice itself, but with very great difficulty and distortion in the laboratory. Principles, on the other hand, are what the laboratory teaches most readily and perfectly, and practice least readily and most imperfectly." The book contains a series of very suggestive experiments, many of which are quantitative in their character, and the work evidently marks an advance in metallurgical instruction. H. L. W.

5. *The Analysis of Steel-works Materials;* by Brearley and Ibbotson. 8vo, pp. 501. London, 1902 (Longmans, Green and Co.).—The wide scope of this book is seen from the following list of the parts into which it is divided: The analysis of steel, of pig-iron, of steel-making alloys; rapid analysis at the furnace; the analysis of ores, of refractory materials, of slags, of fuel;

boiler water, boiler scales, etc.; analysis of engineering alloys; micrographic analysis of steel; pyrometry; miscellaneous notes; bibliography of steel-works' analysis. The authors give full descriptions of the analytical methods which they prefer, and also give summaries of other important methods. The bibliography is elaborate and will be useful, although it refers chiefly to British journals. The book is supplied with many illustrations.

H. L. W.

6. *Electro-chemical Analysis;* by EDGAR F. SMITH. Third edition, revised and enlarged. 8vo, pp. 204. Philadelphia, 1902 (P. Blakiston's Son & Co.).—The appearance of an improved edition of I rofessor Smith's well-known, excellent book is to be heartily welcomed. The work has been much enlarged, and the section devoted to separations has been entirely recast. H. L. W.

7. *The Potash Salts;* by Dr. L. A. GROTH. 8vo, pp. 291. London, 1902 (The Lombard Press).—This book gives an interesting and instructive account of the great German potash industry, including the history of its development, the geology and mineralogy of the deposits and many statistics. It also treats of the applications of potash in industry, agriculture and horticulture. Descriptions of various kinds of mining machinery are also given.

H. L. W.

8. *Elektro-Metallurgie;* von Dr. W. BROCHERS, Dritte Auflage, Erste Abtheilung. 8vo, pp. 288. Leipsic, 1902 (S. Hirzel).—This is the first part of the third edition, much enlarged and thoroughly revised, of a very important work on elektro-metallurgy. The rapid development of this branch of industry makes its description increasingly difficult, but it is evident that the author has accomplished this well. The part under consideration treats of the alkali, alkali-earth, and earth metals, also of copper and partly of nickel. H. L. W.

9. *Physikalische Chemie der Zelle und der Gewebe;* by Dr. RUDOLF HÖBER. 8vo, pp. 344. Leipzig, 1902 (Engelmann).—The theories of osmotic pressure, electrolytic dissociation and mass action are presented in about the usual manner but with constant application to life processes. The work of Loeb on the effects of ions and their electric charges receives favorable notice. The methods used in physico-chemical research are given at some length. Ferments, both organic and inorganic, are discussed, Bredig's work in particular on this subject being reviewed. A short chapter is devoted to the influence of temperature and pressure on equilibria.

The book should be of service to those who are interested in physiological chemistry, where it is not improbable that much progress will be made in the future by applying the theories of physical chemistry. H. W. F.

10. *Electrical Properties of Thin Metal Films.*—Professor J. PATTERSON obtained metallic films by cathode discharges in vacuo on glass strips. The thickness of the metallic deposit was measured by Wiener's interference method (Wied. Ann. xxxi,

p. 629) and a complete account is given of the method of measuring the resistances of the films. The conclusions are as follows:

(1) The specific resistance of the films deposited in vacuo by the cathode discharge is several times greater than the specific resistance of the metal from which they were deposited.

(2) The specific resistance of platinum films which have been subjected to the same treatment remains constant above a thickness of about 7×10^{-7} cm. Below this thickness the increase of specific resistance with decrease in thickness is very rapid.

(3) Heat decreases the resistance of both silver and platinum films, and the thinner the film the greater the decrease. In platinum films the greatest decrease is produced by the electric current.

(4) The values obtained for λ, the mean free path of the corpuscle in the metal, are of the same order as those obtained from the change of resistance produced by a transverse magnetic field. —*Phil. Mag.*, Dec., 1902, pp. 652–678. J. T.

11. *Formation of Ozone by Electrical Discharges in Oxygen.*—E. WARBURG finds that the amount of ozone obtained from the negative discharge is nearly three times that from the positive. An expression is given for the amount of ozone formed.—*Ann. der Physik*, No. 12, 1902, pp. 781–792. J. T.

12. *Examination of Spectroscopic Methods.*—H. KONEN examines the light of various metals produced in liquids—first by the voltaic arc, and secondly by discharges from an induction coil. He refers to the recent observations of Wilsing, and also to those of Hale and Lockyer. He is not able to repeat all the phenomena observed by these investigators, possibly on account of not employing the same conditions.—*Ann. der Physik*, No. 12, 1902, pp. 742–780. J. T.

13. *Does Motion through the Ether cause Double Refraction?*—The negative result of the Michelsen-Morley experiments, and the suggestion of Fitzgerald and Lorentz that the stone platform of Michelsen's apparatus altered its relative dimension when rotated, leads RAYLEIGH to investigate whether the motion of the ether can cause double refraction. The author concludes from his experiments that there is no double refraction of the order to be expected.—*Phil. Mag.*, Dec., 1902, pp. 678–683. J. T.

14. *Scientia, Série Physico-Mathématique: No. 19, L'Électricité déduite de l'Expérience;* par E. CARVALLO. Pp. 91. (C. Naud, Éditeur.)—In a most careful and logical manner M. Carvallo has deduced from the experimental facts of electricity and magnetism the equations of Maxwell's theory and has made clear the significance of the general process employed, by a number of well chosen illustrations. The method is that of Maxwell—the application of Lagrange's dynamical equations to electrical systems—and there is no special originality of treatment; but in clearness of exposition and the avoidance of obscurities the work is admirable and will doubtless make easier the task of many students of Maxwell. A point of special interest is the treatment

of an apparent paradox which occurs in the discussion of Barlow's wheel; a purely mechanical case is given in which there is a similar failure of Lagrange's method for an analogous reason.

No. 20. *Sur les principes fondamentaux de la Théorie des Nombres et de la Geométrie;* par H. LAURENT. Pp. 68.

H. A. B.

15. *Lehrbuch der Physik;* von O. D. CHWOLSON. Deutsche Übersetzung von H. PFLAUM. In vier Bände. Erster Band; pp. xx + 792. (Braunschweig: F. Vieweg & Sohn.)—In 1897 a text-book of physics, in Russian, by Prof. Chwolson of the University of St. Petersburg, was published, and a second and revised edition appeared in 1900. In the meanwhile the work had received such high praise from physicists whose knowledge of the language permitted them to read it that a German translation was undertaken, the first volume of which has recently been issued. Although of large size and comprehensive in character, the work is primarily a text-book for students rather than a rival of such works of reference as Winkelmann's Hand-book; and it is for its pedagogical excellences that it has been especially commended. An examination of the present volume goes far toward justifying in the mind of the reader these commendations; the arrangement and classification are logical and especially convenient for teaching; the statements are clear and exact with most careful discrimination between experimental fact and hypothesis, and the mathematical demonstrations are simple and elegant. But the most striking achievement of the author (considering its difficulty in an elementary text-book) is the constant maintenance of the right point of view and proper perspective; so that the student who uses this book with intelligence can scarcely fail to understand what the object of physics really is, and what are its methods and limitations; the general introduction, in particular, displays these qualities to a marked degree. The second subdivision of the present volume is devoted to mechanics, including wave motion and the elementary theory of potential; the third to apparatus and methods of measurement; the fourth, fifth and sixth to the study of gases, liquids and solids, respectively. The three succeeding volumes in order will deal with sound and radiation, heat, and electricity and magnetism. Although elementary in character, the treatment is very complete, and at the end of each chapter a list of references is given to other books and to the periodical literature of the subject. The book is probably too large and too thorough-going to be used as a text-book in any American college, but it will doubtless be useful indirectly to many teachers. H. A. B.

II. GEOLOGY AND NATURAL HISTORY.

1. *New Mineral Names.*—ANAPITE. A new potassium iron phosphate occurring at Anapa on the Black Sea is given the name Anapite by A. SACHS. The mineral occurs in crystals about

2^{mm} long and $\frac{1}{2}^{mm}$ thick, in plates and radiating columns and also in massive form. It is transparent and of a faint green color. On heating it turns first gray, then black, and finally yellow. Water is given off at 120°. The analysis gave: FeO = 18·07; CaO = 27·77; P_2O_5 = 35·51; H_2O = 18·47; alkalies, a trace; total = 99·82. The formula derived from these results is: $FeCa_2(PO_4)_2 \cdot 4H_2O$. The mineral is easily soluble in HCl and HNO_3. H = 3–4. Sp. gr. = 2·81. Crystallization is triclinic, $a : b : c = 0{\cdot}87566 : 1 : 0{\cdot}59753$, $\alpha = 132° 22'$, $\beta = 106° 47'$, $\gamma = 83° 28'$. Anapite is closely related to messalite but is not identical with it.—*Sitz.-Ber. preuss. Akad. d. Wissensch.*, Berlin, 1902, p. 18–21.

Chalmersite. This new sulphide, which is described by E. Hussak, is a member of the chalcocite group. It was found in the gold mine "Morro Velho," in Minas Geraes, Brazil, where it occurs intimately associated with pyrrhotite and chalcopyrite. It is orthorhombic in crystallization with the axial relations $a : b : c = 0{\cdot}5734 : 1 : 0{\cdot}9649$, which are very close to those of chalcocite. The common forms found on its crystals are *m* (110), *b* (010), *c* (001), *p* (111), *g* (011) and, more rarely, *a* (100). When the crystals appear doubly terminated they show a hemimorphic development having a base at one end and various pyramid and dome faces at the other. Simple crystals are rare, twins with the twinning plane *m* being most common. Contact and cruciform twins are rarer. The crystals are almost always prismatic, occurring in needle-like forms. The faces of the prism zone are strongly striated vertically. It has no cleavage; hardness = 3·5. Luster is metallic, color bronze yellow, often with a brilliant tarnish. It is strongly magnetic. Specific gravity = 4·68. The quantitative analysis by W. Florence gave, Fe = 46·95; Cu = 17·04; S = 35·30; total = 99·29, which yields the ratio of Fe : Cu : S = 3 : 1 : 4. From this is derived the formula: $Cu_2Fe_3S_4$ or $Cu_2S \cdot Fe_2S_3$. Named after G. Chalmers, superintendent of the "Morro Velho" mine. —*Centralblatt f. Min., Geol. u. Palaeon.*, No. 3, 1902, p. 69.

Koenenite. This mineral, which occurs at Volpriehausen in Solling, is described by F. Rinne. It is of a red color resembling some varieties of carnallite, from which it differs, however, in having a fine cleavage. Specific gravity is 1·98. Its crystallization is hexagonal rhombohedral. The analyses show it to be an aluminum, magnesium oxychloride, with varying amounts of water. The formula is $Al_2O_3 \cdot 3MgO \cdot 2MgCl_2$ with 8 or 6 H_2O. Named after Dr. A. v. Koenen.—*Centralblatt f. Min., Geol. u. Palaeon.*, No. 16, 1902, p. 493. W. E. F.

2. *New Forms on Sperrylite;* by Goldsmith and Nicol. (Communicated.)—The following new forms have been observed on crystals of sperrylite from the original locality, "Vermilion Mine," Algoma, Ont.: *b*, $\bar{2}03$; *g*, $\bar{2}05$; *a*, 103; *k*, 114; *m*, 113; *q*, 112; B, 335; and *u*, 212.

3. *Recherches géologique et pétrographique sur l'Oural du Nord dans la Rastesskaya et Kizelowskaya-Datcha (Perm, Russie);* par L. Duparc et F. Pearce. (Mem. Soc. Phys. et d'Hist. nat. de Genève, vol. xxxiv, fas. 2, 4°, pp. 218, pl. 4 and

many figs. in text. Geneva, 1902.)—In addition to the more technical researches in geology comprising the major portion of this volume, it contains also a general account of the region studied, of its physical geography, its orography, hydrography, sketches of its fauna, flora, inhabitants, etc.

The second part of the work treats of the geology and petrography of Mount Koswinsky and the concluding portion is devoted to a similar study of the small mountain Katečhersky. The geology is chiefly the description of the occurrence of the various igneous rocks of the region, which are quite fully described in the petrographical portions of the memoir. They comprise various types of mostly basic rocks, diabases, gabbros, dunites, etc., and diorites, pyroxenites, etc., occurring in dike forms. Of these rocks perhaps the greatest interest attaches to a type of pyroxenites called *Koswite* by the author. It is a melanocratic, granular rock composed of varieties of pyroxene, olivine, hornblende, chromiferous spinels and magnetite; the latter mineral plays the part of the xenomorphic cement.

Several analyses of the different types of koswite are given, from which we select the two following :

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Ign.	MnO	Cr_2O_3	
(*a*)	41·44	5·80	10·46	9·93	13·36	19·53	0·22	0·05	0·57	= 101·36
(*b*)	40·15	4·60	12·24	10·87	15·01	17·26	0·40	---	0·58	= 101·11

Very noticeable in these is the enormous amount of iron and the large amount of lime in comparison with the magnesia ; these are magmas of types quite distinct from those of most of the peridotites. L. V. P.

4. *Mineralogy ;* by HENRY A. MIERS, Professor of Mineralogy in the University of Oxford. 8vo, pp. 584. London, 1902 (The Macmillan Co.).—As stated by the author in his preface the volume is not intended as an exhaustive book of reference, but rather a treatise in which the student will find all that is required for an elementary acquaintance with the subject of mineralogy, the species described being those which may be found in all museums, and most of which may be collected by the students themselves. Special stress is laid upon accurate measurements and determinations, and the intelligent use of the goniometer and microscope. After a brief introduction the subject of crystallization is treated in a thoroughly scientific manner, yet too briefly, it is believed, to satisfy the wants of elementary students. The chapters on the regular conjunction of crystals, on vicinal faces, on the measurement of crystals and on the physical properties characteristic of crystals are brief, but admirably illustrated and full of useful suggestions. The chapter on the optical properties of crystals is one of the best features of the book, and is a very exhaustive and suggestive presentation of this most important subject. By the use of the indicatrix many obscure and perplexing phenomena of uniaxial and biaxial crystals are explained. Following are short chapters treating of the general physical properties of minerals, chemical properties, isomorphism, pyrognostic and microchemical tests, and spectroscopic examination.

About one-half of the book is devoted to the description of the more important mineral species. The descriptions have been very carefully written and give much information which will be welcomed by all advanced students of mineralogy. A noteworthy feature of the book is the large number of excellent, shaded, half-tone illustrations of crystals and crystal aggregates, skilfully drawn by the author's sister, Miss J. Miers. The ordinary outline crystal figures are also well executed, and the text is fully illustrated, there being in all 666 figures and two colored plates.

At the close of the volume there are useful lists of the principal minerals, tabulated according to the chemical classification; according to their mean refractive index in sodium light; birefringence; divergence of the optical axes, 2E, 2V, and 2H; lastly, according to specific gravity. The volume is well printed on excellent quality of paper, and in this respect may well serve as a model for books of its kind. S. L. P.

5. *Zur Fossilen Flora der Polarländer;* von A. G. NATHORST. Erster Teil. Dritte Lieferung: *Zur Oberdevonischen Flora der Bären-Insel* (mit 14 Tafeln). Kongl. Svenska Vetenskaps-Akademiens Handlingar, Bandet 36, No. 3. Stockholm, 1902.—The great age of the plants described in this contribution gives it an especial interest. The Bear Island lies about midway between the North Cape and Spitzbergen. And certain fossil plants described from it by Heer thirty years ago were considered as being of Carboniferous age. Nathorst, however, finds from both faunal and floral evidences that the several beds from which he has in the past few years secured upwards of thirty species of Filicales, Sphenophyllales, Calamariales, and Lycopodiales, are Upper Devonian. He says: "One needs but to inspect briefly the florula of the Bear Island to see that vascular plants must have existed for an exceedingly long period previous to Upper Devonian time." G. R. W.

6. *Beiträge zur Kenntniss einiger Mesozoischen Cycadophyten* (mit 3 Tafeln und 1 Textfigur); von A. G. NATHORST. Kongl. Svenska Vetenskaps-Akademiens Handlingar, Bandet 36, No. 4. Stockholm, 1902.—In the foregoing paper Nathorst describes an exceedingly interesting series of cycadaceous fructifications, in part accompanied by stems or leaves, all of which are of late Triassic age. That very important fossil *Williamsonia angustifolia* Nathorst (=Anomozamites minor) from the Upper Keuper sandstones of Hör in Skone is redescribed from additional specimens, and many figures are given. This plant has a slender, freely branching stem, *Nilssonia*-like leaves, and fructifications that are obviously Bennettitean. It is highly suggestive of the wide range of form that the Bennettites-like plants must have exhibited. Among the specimens figured and described there are some unmistakable ovulate strobili of the *Williamsonia* and *Bennettites* type. As compared with either of these genera there are no fundamental differences apparent in these fruits. Like-

wise, in the case of the somewhat different accompanying fructification often found attached in the forks of the stems, the reviewer believes with Nathorst that a bisporangiate strobilus with shed staminate organs is represented, and that the central pear-shaped axis is ovulate, and may or may not have been functional. It was probably not functional, but one cannot yet say positively whether this plant was monoecious, dioecious, or bisexual, etc. But to continue to include it in the genus *Williamsonia*, the reviewer believes to be inadvisable. In the first place the striking differences of stem and leaf might well in themselves be held of generic value. Also the unknown microsporophylls may have varied considerably from those of *Williamsonia* and *Bennettites*. For instance, though more ancient, they may have been more reduced and stamen-like in form.

Among the other cycadaceous forms described the isolated fruit, considered as representing the new genus *Cycadocephalus*, is also of much interest. If, as Professor Nathorst believes, this fossil consists in a series of basally adnate carpellary leaves, it is certainly generically different from all other known cycadaceous plants. But I am strongly of the opinion that it is a partially expanded bisporangiate strobilus like that of *Bennettites*, and that the elliptical bodies to be seen ranked along the sides of the exposed sporophyll rachis, at several points, are simply large and flattened pollen-bearing synangia. That a true Carpellary or Seed-bearing Disk may have been borne by some extinct cycadaceous plant is indeed both possible and probable, an opinion I have emphasized before. But as yet it does not seem that we have indisputable evidence of any such. As I have stated before, I would rather regard Williamson's so-called carpellary disk as staminate and not seed-bearing. The regularly arranged scars which he doubtless saw on the rays or fronds of certain specimens may better be considered to have been left by fugacious synangia-bearing pinnules than by shed seeds. Whether the fronds in the specimen described by Professor Nathorst are once pinnate or not, is, I think, not disclosed. But I may add that by developing a bisporangiate Bennettitean strobilus from its matrix of bracts I have found quite similar surface details.

The discovery of "Antherangia" in the leafy crown constituting the type of *Dioönites spectabilis* "suggests the existence of another class of Cycadophytes,—the Dioönitales." It would seem possible that pollen might be found in some of the sporangia, and it is much to be hoped that other material may be secured illustrating this unique type of fructification. G. R. W.

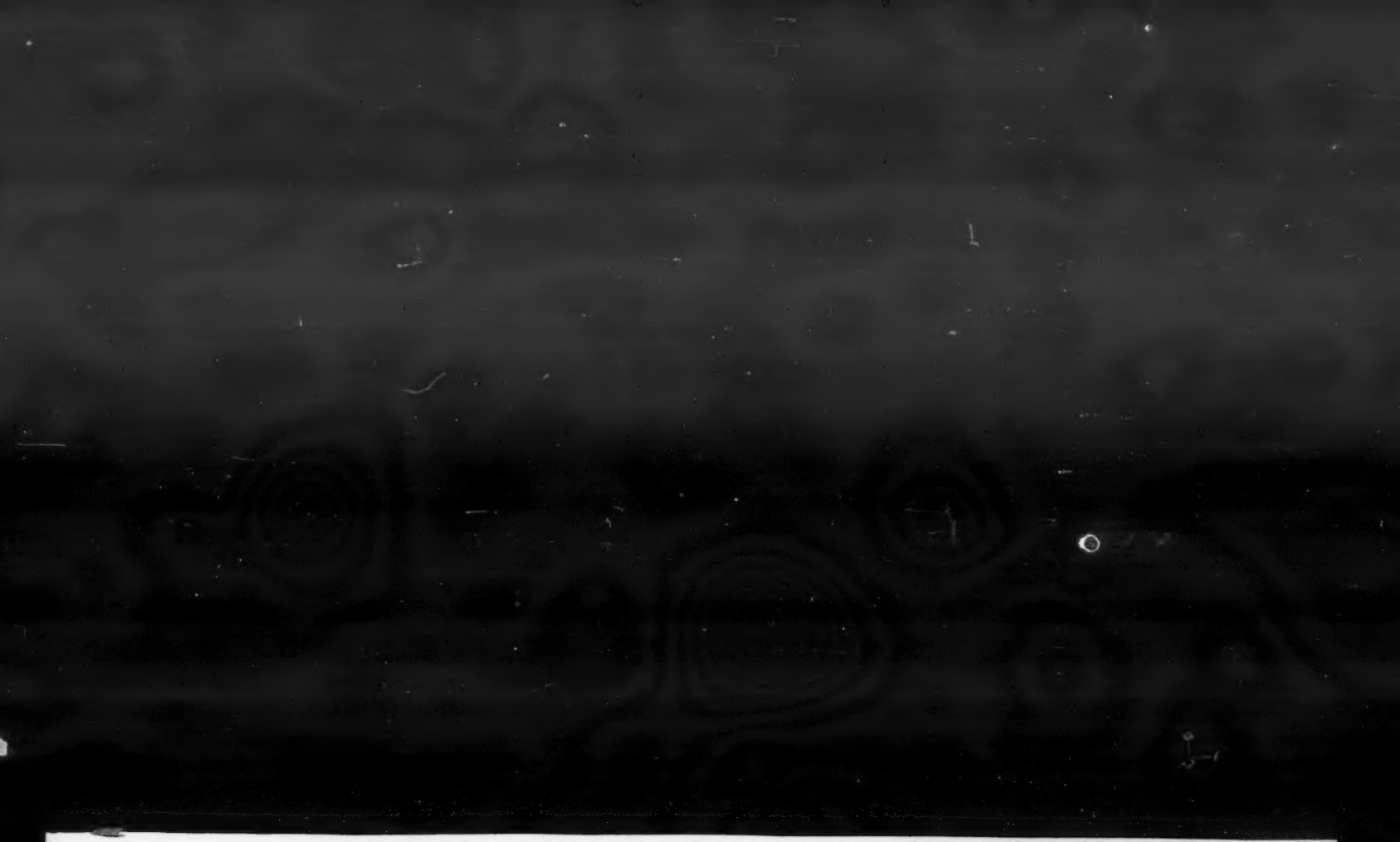
7. *A Flora of the South Fork of Kings River;* by ALICE EASTWOOD. 96 pp., 6 figs. Publ. No. 27, Sierra Mountain Club. —Miss Eastwood's Flora of the South Fork of Kings River from Millwood to the Headwaters of Bubbs Creek is the twenty-seventh of a series of publications of the Sierra Club, an association with the following admirable purposes: "to explore, enjoy, and render accessible the mountain regions of the Pacific Coast;

to publish authentic information concerning them; to enlist the support and coöperation of the people and Government in preserving the forests and other natural features of the Sierra Nevada Mountains." The publication as a local flora is unusual in character, for although it relates to a region little explored botanically, rarely visited, and accessible only by pack-train, the paper has been very carefully elaborated as a descriptive flora with ordinal and generic keys and a pretty full characterization of each species. No claim of completeness is made. As in most local floras, the bryophytes and thallophytes are omitted. Furthermore, the grasses, sedges, and rushes, being groups of too great technicality to be of special interest to the tourist, are passed over with brief mention. The descriptions are clear and well contrasted and the author shows excellent judgment in the limitation of species, nomenclature, etc. While fully agreeing with the sentiment expressed in a brief preface, that this flora is far more valuable than the "more descriptive and popular article," which might have been published in the same compass, we cannot help expressing a regret that time and space did not permit some phytogeographic supplement or statistical summary regarding the elements of the interesting vegetation here treated.

B. L. R.

8. *A Botanical Survey of San Jacinto Mountain;* by HARVEY MONROE HALL. Imper. 8vo, 140 pp., 14 pls. (University Press, Berkeley, California.)—Mr. Hall's publication upon the phytogeography of San Jacinto Mountain is of interest from many points of view. It is the first of a new series of scientific papers emanating from the botanical department of the University of California and is at once striking by the excellence of its typography, its clear and attractive illustrations, methodical arrangement, and full index. The region covered by Mr. Hall's studies is one which is well adapted to phytogeographic records, since it exhibits in a pretty restricted area exceedingly diverse climatic and floral conditions, and illustrates with exceptional clearness several well marked life zones. Four of these are delimited with much detail upon a colored contour map of the region. The author has wisely avoided the use of any complex system of phytogeographic terminology and has employed his space to much better advantage by carefully defining the expressions used. The paper closes with a systematic catalogue of the spermatophytes observed on San Jacinto Mountain in and above the yellow pine belt (transition zone). This catalogue, in which several new species and varieties are characterized, not only possesses value as the local flora of a very interesting mountain region, but gives confidence in the thoroughness of the phytogeographic methods of the author, and loses nothing from the fact that it is not lumbered up with needless bibliographical references to common species and well known synonymy. B. L. R.

III. Miscellaneous Scientific Intelligence.

1. *Development and Evolution, including Psychophysical Evolution, Evolution by Orthoplasy, and the theory of Genetic Modes;* by James Mark Baldwin. 395 pp. (The Macmillan Company, 1902.)—A convenient handbook of the theory of Orthoplasy as held by Principal Lloyd Morgan, Professor H. F. Osborne and especially by Professor James Mark Baldwin, is found in a book published under the title Development and Evolution, by the latter author. About half of the volume has appeared in shorter published articles more or less revised in their present form, while the remainder is an expansion of the subject on its psychological side. A brief definition of Organic Selection is given on p. 151: "Organic Selection: the perpetuation and development of congenital variations in consequence of individual accommodations." And the author's point of view may be gathered from a longer quotation. After mentioning objections to both neo-Darwinism and neo-Lamarckism, the author writes: "There is another principle at work whose operation is directly supplementary to natural selection—the principle already described above under the name of Organic Selection. Put very generally, this principle may be stated as follows: acquired characters, or modifications, or individual adaptations,—all that we are familiar with in the earlier papers under the term 'accommodations,'—while not directly inherited, are yet influential in determining the course of evolution indirectly. For such modifications and accommodations keep certain animals alive; in this way occur the variations which they represent from the action of natural selection, and so allow new variations in the same direction to arise in the next and following generations; while variations in other directions are not thus kept alive and so are lost. The species will, therefore, make progress in the same directions as those first marked out by the acquired modifications, and will gradually 'pick up,' by congenital variation, the same characters which were at first only individually acquired. The result will be the same, as to these characters, as if they had been directly inherited," etc. (p. 138.) We reach a more specific and perhaps clearer idea of the author's thesis by noting his phrasing of the means and results of the fourteen different sorts of selection the author has culled from various sources (p. 166). The means of *Natural selection* are listed as *struggle for existence* and *inherent weakness;* the results are *Survival of the fittest individuals,* and (2d) the *Destruction of unfit individuals.* In contrast *Organic selection* has as means *accommodation, modification* and *growth processes,* and the results the *Survival of accommodating and modified individuals.*

From a perusal of the book one is impressed with the multiplicity of forms in which ideas about evolution can be phrased, and with the wonderful evolution of evolution since the publication of the Origin of Species. H. S. W.